Unit–V

Q. 23. ***Describe the structure and development of angiospermic ovule.***

Or, ***Describe the structure and types of angiospermic ovules along with diagrams.***

Ans. **Ovule or Megasporangium**

Structure of the Ovule : The ovule is attached to the placenta by a slender stalk known as **funicle**. The point of attachment of body of the ovule to its stalk or funicle is known as **hilum**. In the inverted ovule the funicle continues beyond the hilum along side the body of the ovule forming a ridge called **raphe**. The main body of the ovule is called the nuceellus and is surrounded by two coats the integuments.

A small opening is left at the apex of the integument which is called the **micropyle**. The base of the nucellus from which the integument spring is called the **chalaza**.

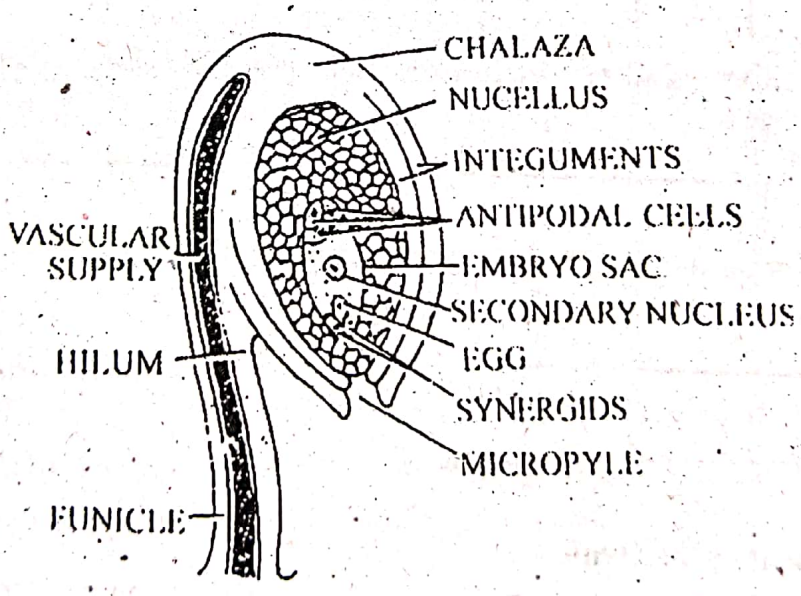

Fig. 23.1. V.S. of a mature ovule showing its internal structure in detail.

There is a large oval cell lying embeded in the nucellus towards the micropylar end is the **embryo sac**. Normally the embryo sac contains eight nuclei and scanty cytoplasm when mature. Three of the nuclei form a group at the micropylar end and are generally scaparated by delicate walls. The median nucleus functions as the egg (oosphere) and gives rise to the embryo after fertilization. The two lateral nuclei called the synergids by **Strasburger**, which

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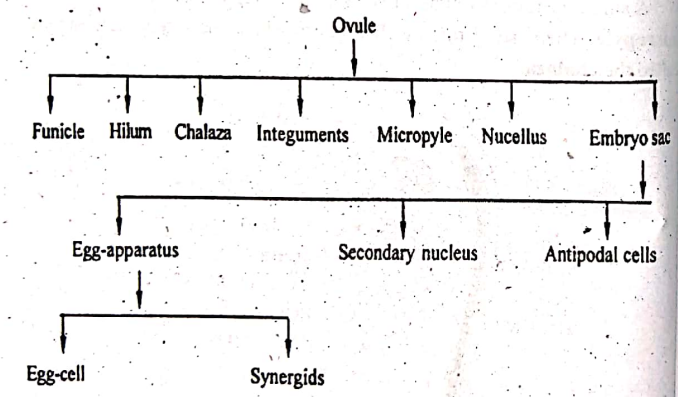
function as co-workers of the oosphere. These three are collectively called the **egg apparatus**. At the chalazal end is another group of three nuclei which are separated by delicated walls called the **antipodals**. They play no part in the fertilization and disappear after some time. They may multiple in some cases or may have nutritive function.

In the centre of the embryo sac, between the egg apparatus and antipodal cells is formed a pair of nuclei lying close together, are called the **polar nuclei**. They lie free in the cytoplasm of the embryo sac and sometimes unite before fertilization forming the **secondary nucleus**. In all cases they unite jointly with one of the two male nuclei from the pollen tube. This fusion is known as triple fusion or double fertilization the product of which is the primary endosperm nucleus.

The various parts of mature ovule may be studied with the help of he following chart :



Development of the Ovule

The main body of an ovule is the nucleus which is central parenchymatous mass may be rounded or oval. The nucleus arises as a small protuberance on placenta of the ovary. It originates from the sub-epidermal cells which divides repeatedly. These actively, dividing cells are situated in the hypodermal layers. The placental epidermis increases in size due to anticlinal division and extends over the protuberance. The protuberance is somewhat hemispherical which elongates very rapidly so that the basal region becomes elongated forming a supporting stalk the funicle of the ovule.

Before the formation of the funicle the hypodermal cells at the apex of the nucellus are differentiated due to large nuclei and dense cytoplasm which are called archesporial cell.

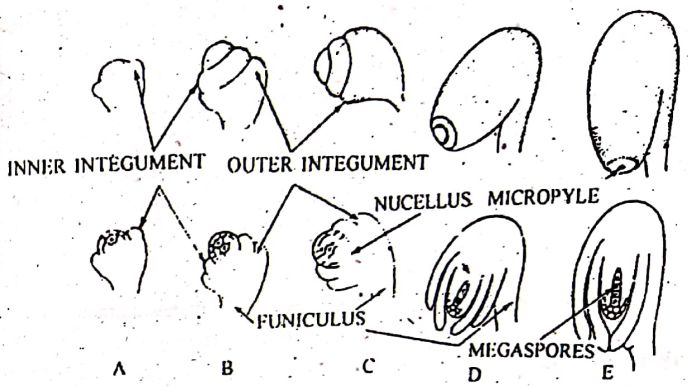


Fig. 23.2 Developmental stages of ovule.

As soon as the rchesporium is developed, the first or inner integument also appears forming a ring like swelling around the nucellus. The outer integument appears later on and its development is very slow. There is much variation between families with regard to the presence of two integuments. The number of generally constant throughout a family with a few exceptions.

Two integuments are found in most families of the Archechalmydeae and of the Monocotyledons. Excetional families like are also unitegmic. In **Monocotyledons**, *Crinum* has no integuments. Unitegmic ovules are characteristics of the **Metachlamydeae**. The single integument is usually massive.

In few cases supernumerary covering to the ovule are also found. A third integument of **aril** arises from the base of the ovule and over grows the others but remains distinct from them. The **aril** doesn ot form the part of the seed coat but develops as an outer separate covering of separate colour and texture e.g., the white fleshy edible part in **Litchy** is aril, found outside the seed coats. Of a different origin is the **caruncle** found in several members of **Euphorbiaceae**, which arises by the proliferation of the integumentary cells at the micropylar region.

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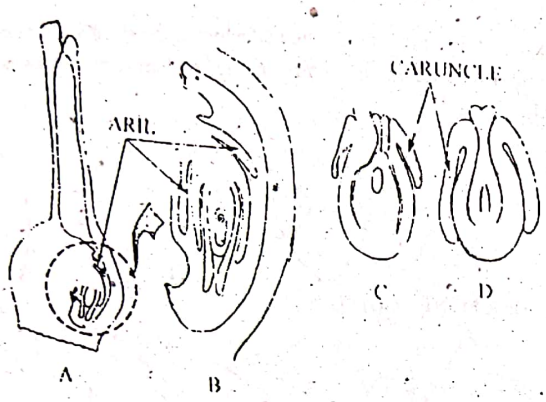

Fig. 23.3. Development of the aril in ovule. (C-D) Development of carnuncle in the ovule from the integuent layer.

Types of Ovules

There are six types of ovules :

(1) Orthotropous (*Orthos* = **straight;** *tropous* = **turn**)

Here the body of the ovule is straight or upright. The **chalaza** and **hilum** lie close together and the **micropyle** is situated at the other end. This is considered to be the most primitive type of ovule and is found in *Polygonum* sp. *Rumex vesicarius*, *Piper betle*, *Piper longum* and *Casuarina* sp.

(2) Anatropous (*Ana* = **backward;** *tropous* = **turn**)

In this case the body of the ovule is completely bent over and fused alongwith the funicle is called the **raphe**. The **hilum** and **micropyle** lie close together and **chalaza** is situated at the other end. This the commonest type of ovule and found in **Pea** (*Pisum sativum*), **Bean** (*Dolichos lablab*), **Castor** (*Ricinus communis*).

(3) Hemianatropous (or transverse)

In this type of the body of the ovule is placed transversely at right angles to the **funicle**. The **hilum** and **micropyle** are all separated from one another. This is quite a rare type and is found in **Duck weed** (*Lemna pauicostata*), **Poppy** (*Papaver somniferium*).

(4) Campylotropous (*Kampylos* = **curved,** *tropous* = **turn**)

In this type the body of the ovule is curved and bent round like a **horse shoe**. The **hilium, chalaza** and **micropyle** all lie close together. It is found in **Mustard** (*Brassica compestris*).

(5) Amphltropous

In this type ovule is more curved and the embryo sac becomes horse shoe shaped.

(6) Circinotropous

In this type the **funicle** is exceptionally long so that it completely encircles the ovule. It is found in *Opuntia* sp. and *Cacti.*

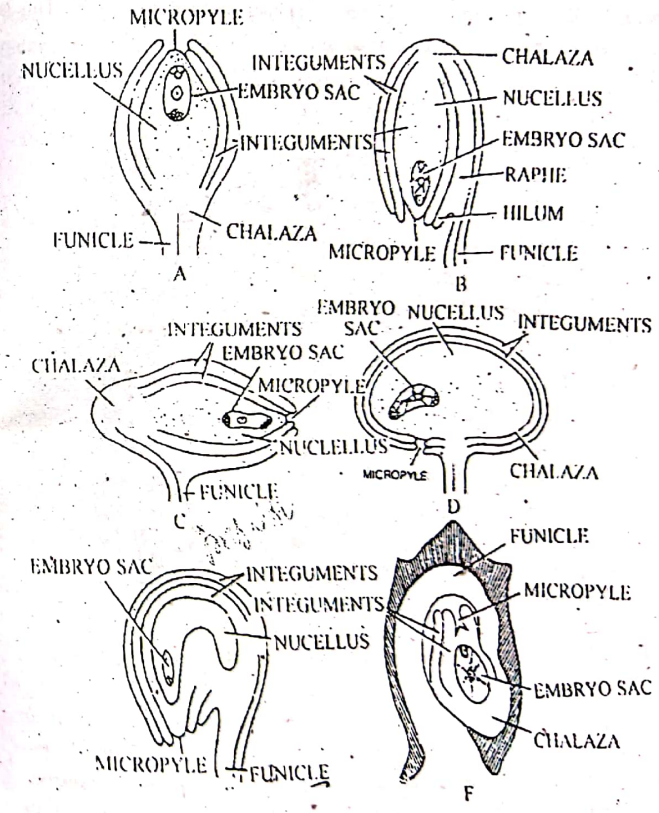

Fig. 23.4. Type of ovule. (A) Orthotropous, (B) Anatropous, (C) Hemianatropous (D) Campylotropous, (E) Amphitropous (F) Circinotropous.

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Q. 24. ***Describe the process of Megasporogenesis.***

Or,

Write an essay on Megasporogenesis.

Ans. Megasporogenesis : The nucleus is a sporophytic structure, the cell of which gives rise to archesporium and ultimately to megaspores after reduction division. The archesporial cells are hypodermal in origin. Generally one cell of the nucellus situated directly below the epidermis becomes more conspicuous due to its large size, denser cytoplasm and larger nucleus. This is now called as **primary archesporial** cell.

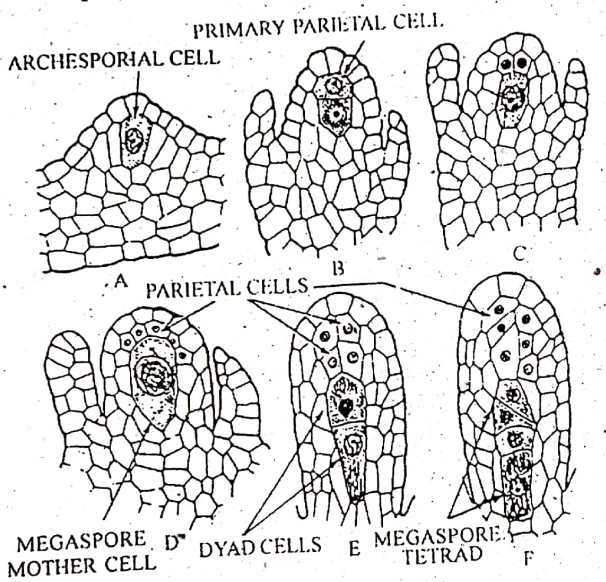

Fig. 24.1. Magasporogenesis—Stages of the development of megaspore mother cell.

The primary archesporial cell divides by a periclinal wall to form an outer primary parietal cell and an inner primary sporogenous cell. The parietal cell may not divide at all or it may divide. The **primary sporogenous cell** usually behaves as a single **megaspore mother cell** without undergoing any further division. This cell divides by reduction division so that four haploid megaspores are formed which are arranged in a linear tetrad.

As a rule only one megaspore of the tetrad becomes functional and the remaining three degenerate. Mostly the lower most chalazal megaspore is functional. The functional megaspore grows and enlarge in size and gives rise to the embryo sac.

The Female Gametophyte or Embryo sac

The functional megaspore is haploid and is the starting point of the female gametophyte. In angiosperm the megaspore nucleus does not proceed beyond 8 nucleate stage during the development of embryo sac or the female gametophyte. The embryo sacs are classified on two main character. The first is the number of megaspores taking part in the formation of the embryo sac and second is the number of nuclei in the mature sace.

Prof. Maheshwari (1950) has classified the development of embryo sacs into the following three classes, depending upon the number of megaspore cells and megaspore nuclei taking part in the development.

1. Monosporic embryo sacs.
2. Bisporic embryo sacs.
3. Terasporic embryo sacs.

The main classes of the embryo sacs constitute the following ten types depending of the number of the nuclei.

Prof. Maheshwari (1950) has classified the various types of embryo sac in Angiosperms on the basis of their development.

(1) Monosporic

(When four megaspores are formed)

(A) Eight nucleate embryo sac—*Polygonum type*

(B) Four nucleate embryo Sac—*Oenothera type*

(2) Bisporic

(When two megaspores are formed)

(A) Eight nucleate embryo sac—

(i) Adoxa type

(ii) Fritillaria type

(iii) Plumbago type

(3) Tetrasporic

(When megaspores are not formed only nuclei are formed in megaspore mother cell)

(B) Four nucleate embryo sac—

(i) Plumbegella type

(C) Sixteen nucleate embryo sac—

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(i) Drusa type
(ii) Penaea type
(iii) Peperomia type

(1) Monosporic Embryo Sac

The Polygonum type : Eight Nucleate embryo sac—This is the normal type of female gametophyte or embryo sac. Here the **megaspore mother cell** nucleus after dividing mitotically forms four haploid megaspores which are arranged in a linear tetrad of which the lower most (chalazal) **megaspore** is functional. The nucleus of the functional megaspore divides by simple division into two nuclei. These two nuclei move to opposite poles, one going to the **micropylar end** of the embryo sac and the other to the **chalazal end**. Then as a result of second nuclear division two nuclei are formed at each pole. This is followed by the third nuclear division which results in the formation of eight nuclei, four at each pole. During these changes the embryo sac increases in size and a big vacuole is formed in its centre. Of the four nuclei at the micropylar pole, three are organised into the **egg apparatus**, the central cell of the egg apparatus is the egg, ovum or **oosphere**. The other two cells are the **synergids** which help in the process of ferti lization. The synergids are usually somewhat pear shaped. Similarly three nuclei at the **chalazal end** form three thin walled **antipodal cells**. Now one free nucleus remains at each pole. These two nuclei i.e., one **micropylar polar nucleus** and one **antipdial polar nucleus** move to the centre of the embryo sac and fuse there to form the **secondary nucleus** which therefore, is diploid. Sometimes the two polar nuclei remain lying side by side and fuse together at the time of fertilization.

The name *Polygonum* has been given to it because it was first described in *P. divaricatum* by **Strasburger** (1879).

Struture of the Normal Embryo Sac

The embryo sac is a larger structure which is surrounded by cellulose wall. It contains eight nuclei of similar size with cytoplasm. At a later stage, these eight nuclei are arranged in two groups of four nuclei at opposite poles an vacuole appears in the centre containing sap. Near the approach of fertilization the central vacuole is divided into many small vacuoles and the secondary cytoplasm is accumulated around the two polar nuclei which have been fused in the centre of the sac. The cytoplasm may contain a large number of starch grains which disappear after fertilization.

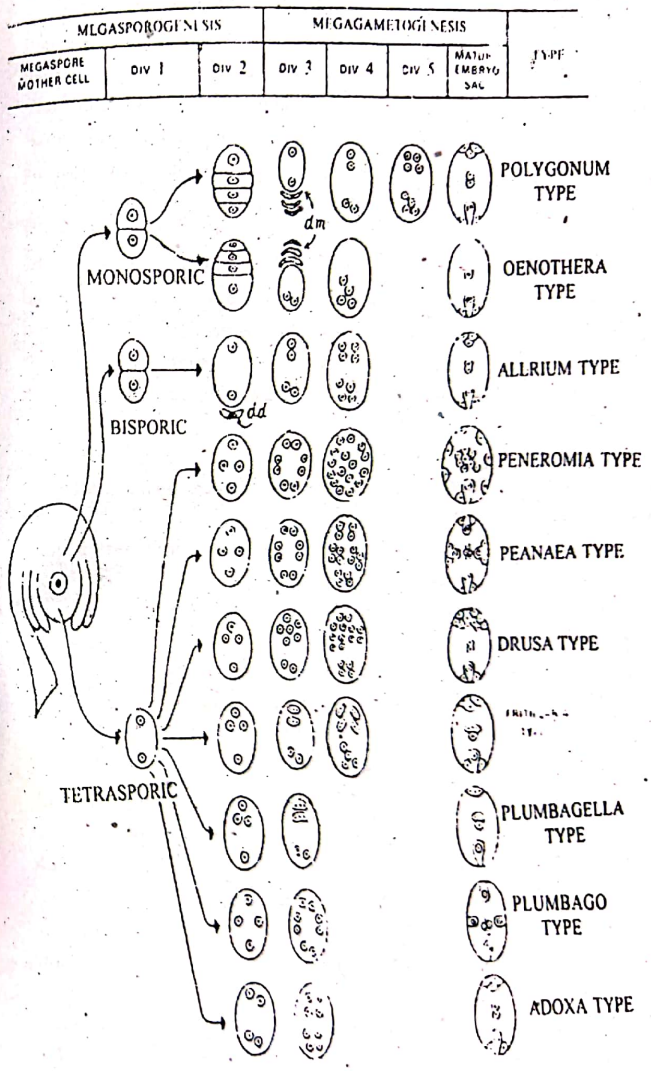

Fig. 24.2. Development of Monosporic, Bisporic, Tetrasporic embryo sacs in different plants.

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The embryo sac enlarges in size either by the destruction and absorption of some of the inner layers of nucellar tissue or by destroying the entire nucellus so that the embryo sac wall becomes very closer to the inner integument and it is generally cuticularized. After the formation of eight nuclei they take their characteristic position, the wall formation takes place at both ends simultaneously but where there is any difference it has always been seen that the antipodal cells are formed before the micropylar cells.

(i) The Synergids—Normally two synergids are found on either side of the egg, they are similar in size. The name synergids has been given by **Strasburger** as they help in fertilization, after which they are of no use and disappear. In exceptional cases they disappear before fertilization. The pointed ends of the synergids are attached to the apex of the embryo sac and th eir lower rounded ends hang into the space of the embryo sac. Their walls are made up of cellulose.

The structure of tyhhe synergid has been known since 1856 but its function is not yet well understood. However the synergid helps in performing the following functions :

1. It protects the cell from bursting at the upper end during fertilization.
2. The pollen tube generally enters through it.
3. It has a secretory function in attracting the pollen tube during its entrance.
4. It is quite tough and durable as it remains upto the last.
5. The lower large, rounded end of each synergid contains a large vacuole which also plays an important part in fertilization.

Sometimes the synergids show abnormal behaviour also.

(ii) The egg (oosphere)—Its position is really lateral to the synergids but it hangs down below them so as to appear that the oosphere cell is attached to the base of the synergid cells. The oosphere contains a **female generative cell**. The nature of the oosphere membrane is of great interest. The upper part is made of cellulose which remains in contact with the synergids, the lower free, portion seems to have only plasmatic membrane until after fertilization.

In the cytoplasm of oosphere apart from the nucleus, certain plastids are also found which manufacture starch found in it. The nucleus of the oosphere is larger than the nuclei of the synergids. The nucleolus is also larger in size, it begins to increase in volume as the time of fertilization approaches.

As the maturation of the oosphere nucleus increases its stain ability decreses . The chromatin first takes a prophase like structure, then there is a discharge of nuclei acid from the chromosomes, which take on a chromomeric structure. The chromomeres later on also disappear and ultimately the nucleus loses its all chromatinity. This condition of the nucleus remains untill the nuclear fusion takes place.

(iii) The polar nuclei—In the eight nucleate embryo sac one nucleus at each end i.e., micropylar and chalazal of the embryo sac migrates towards the centre of the sac. These nuclei unite either before fusing or after the entry of the pollen tube into the sac and the product of their union is called as the **secondary** embryo sac nucleus, the central nucleus or the primary **endosperm nucleus**.

This endosperm nucleus and the cytoplasm around it is known as the primordium of the endosperm.

In majority of Angiosperms fusion of the polar nuclei takes place before fertilization. The endosperm nucleus moves very close beneath the oosphere or it remains in the centre. It never moves towards the antipodal cells.

(iv) The Antipodal Cells—Normally there are three antipodals though there are few exceptions. They are separated by thin cell walls which are first plasmatic later becomes cellulosic.

In much narrow embryo sacs whose growth is restricted the number of antipodal cells may be reduced or less tan three. Sometimes abnromal enlargement of the antipodal cells takes place e.g., *Crocus*, *Kris* etc.

Their main function is to suply nutrition to the embro sac. In the growing embryo sac the nucellus is detroyed and the inner integument is also used up. The main supply of water and food materials come from the chalaza and enter the sac at the antipodal end. Sometimes the antipodal cells become aggressive and develop into chalazal haustoria.

(2) Bisporic Embryo Sac

Allium Type : Eight Nucleate Embryo Sac

Strasburger (1979) has described bisporic embryo sac development in *Allium fistulosum*. The megaspore motehr cell divides to form two dyad cell. Either the lower (*Allium*) or the upper cell (*Scilla*) of this dyad may develope. The nucleus divides to form 2, 4 and then 8 nuclei, which are arranged normally in the embroy sac. This type of embryo sac is found in several monocot families e.g., **Liliaceae, Amaryllidaceae** and **Orchidaceae**. Among dicots it is found in Podostemaceae, Balanophoraceae and Loranthaceae.

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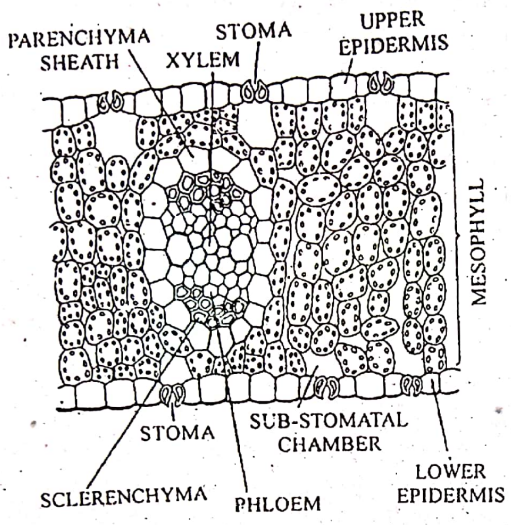

Fig. 24.3. Allium type : Development stages of Bisporic, 8-nucleate embryo sac.

(3) Tetrasporic Embryo sac

Adoxa Type : Eight Nucleate Embryo Sac

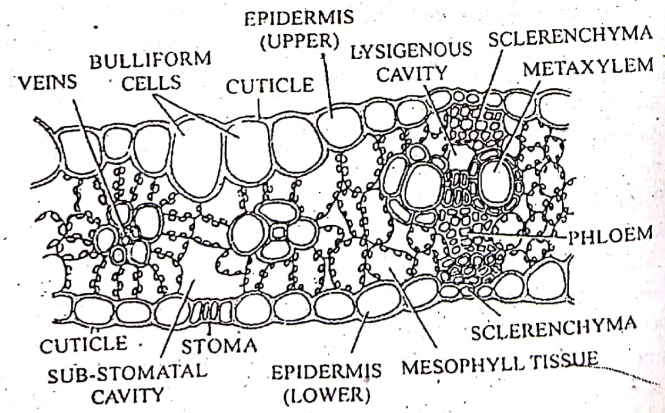

Fig. 24.4. Adoxa type embryo sac : Developmental stages of Tetrasporic, 8-nucleate embryo sac.

This type of the development of embryo sac has been studied by **Jonson** (1879-1880) in *Adoxa-moschatellina*. The nucleus of the megaspore mother cell divides twice to give four megaspore nuclei, without cell division and these divide again once to form eight nuclei which are normally arranged. In this eight nucleate of embryo sac is very less commonly found only in *Adoxa* and *Sumbucus* and in some species of *Ulmus*, *Tulipa* and *Erythronium*.

Penaea type—This type of embryo-sac was first reported by **Stephans** (1909) in *Penaea*, *Sarcocolla* and *Brachyosiphon*. Like Peperomia type, the embryo-sac is 16-nucleate; the nuclei lie in four distinct quadrat arranged cross wise one each at the ends of the embryo-sac and two on sides. Now from ecah quadrat, a nucleus moves in the centre to form a polar nucleus where all the four polar nuclei fuse together to form a secondary nucleus. The three nuclei situated at the micropylar end organise into an egg and two synergids.

Such a type of embryo-sac is know to occur in many families, like Malpighiaceae, Combretaceae, Euphorbiaceae, etc., **Maheshwari** and **Johri** (1941) found in *Acalypha indica* that there are found pairs instead of triads as normally observed. There are 8 polar nuclei in the centre and at the micropylar end, the egg apparatus consists of only one synergid and an egg.

Drusa type—This type of embryo sac development was first reported by **Hokasson** (1923) in ***Drusa oppositifolia*** (Fam. Apiaceae). This type of embryo-sac is also 16-nucleate. The mature embryo-sac comprises a normal egg apatatus (1 egg, 2 synergids), two polar nuclei and 11 antipodal cells.

Q. 25. ***Give an account of the development stages of microsporogenesis and male gametes in angiosperms.***

Or, Give an illustrated account of microsporogenesis in angiosperms.

Ans. The **microspore mother cell** is diploid (2X) which undergo meiotic division to form four hapolid (X) microspores. The first meiotic division is reductional during which the number of chromosome is reduced to half. The second meiotic division is simple, thus four haploid nuclei are formed which produce four haploid microspors.

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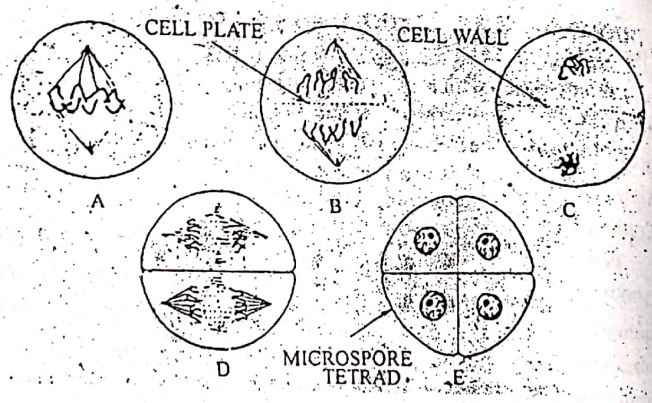

Fig. 25.1 Successive type of division showing the formation of microspore tetrad.

Cytokinesis

It refers to the wall formation. It may show many variations. Many the wall formation, after the reduction division of the microspore mother cells, is of following types :

(1) Successive Type of Division—In this case a cell plate is laid down immediately after the 1st meiotic division and another in each of the two daughter cells after the second division. This type of division is found in **Monocots** and **few Dicot** families like **Asclepiadaceae** and **Apocynaceae.**

(2) Simultaneous Type of Division—In this type no wall is laid down after the first division and the mother cell becomes separated all at once into four parts after both meiotic division are over. It is found in few **Monocot** families *e.g.*, **Liliaceae, Palmae** and **Iridaceae.**

The question as to which of the two modes of tetrad formation is primitive and which is the more advanced is difficult to decide. The simultaneous is more primitive and the succesive type is derived.

The Arrangement of Microspores

After the meiotic division of the microspore mother cells, four haploid microspores are formed which are arranged in tetrad. There are various ways of the tetrad formation which are given below :

(A) Tetrahedral **(B) Isobiateral**
(C) Decussate **(D) '⊥' shaped** **(E) Linear**

(A) Tetrahedral—The microsproe mother cell divides meiotically and forms group of 4 microspores which are hating 4 triangular faces, this

arrangement of microspores is called tetrahedral arrangement, which is very commonly found.

(B) Isobilateral—The microspore mother cell divides meiotically into symmetrical halves by two distinct planes to form 4 microspores. This type of arrangement of pollen grains is very common in Monocots.

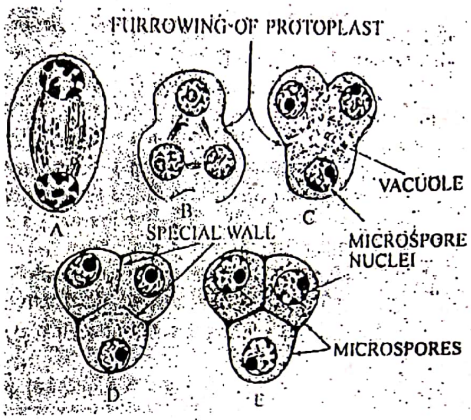

Fig. 25.2. : Simultaneous type of division showing formation of mierospores from microspore mother cell.

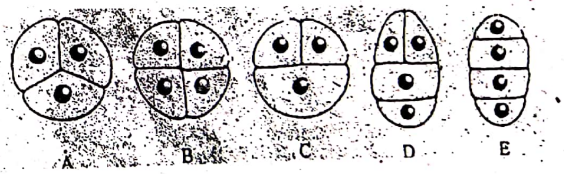

Fig. 25.3. Showing the various type arrangement of microspores in mother cell after meiosis. (A) Tetrahedral (B) Isobilateral (C) Decussate (D) '⊥' shaped (E) Linear

(C) Decussate—The microsproe mother cell divides melotically and form 4 microspores. The microspores are arranged in pairs due to wall formation, but each pair is a right angle to the one above and below it. This type of arrangement of pollen grains is found in *Magnolia.*

(D) Inverted '⊥' Shaped—The microspore mother cell divides meiotically. In the first meiotic division two cells are formed each containing a nucleus.

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DuringIInd meiotic division, out of these two cells one divides by a vertical division and the other by a transvere division. Thus 4 microspores are formed which are arranged in an inverted '⊥' shaped fashion, it is found in *Aristolochia.*

(E) Linear—The microspore mother cell divides melotically and transverse walls are always formed during I and II meiotic division. All the 4 microspores are arranged in a line, having parallel edges. This type of arrangement of pollen grains is found in *Halophila.*

Usually the microspores (pollen grains) separate very soon from one another. In *Typha, Pagonia, Crytostegia* and *Drosera* the pollen grains do not separae apart but remain adhered in tetrad they are thus called, **Compound pollen grains.**

In *Calotropis procera* (Madar) and *Orchis mascula* (Orchid) the pollen cells do not form pollen grains but unite together to form **polinia**. Each pollinium possesses a short stalk and a sticky disc.

Dehiseence of the Anthers

When the pollen grains are mature they exert some pressure on the wall of the anther, which bursts and sets free the pollen grains. At the time of

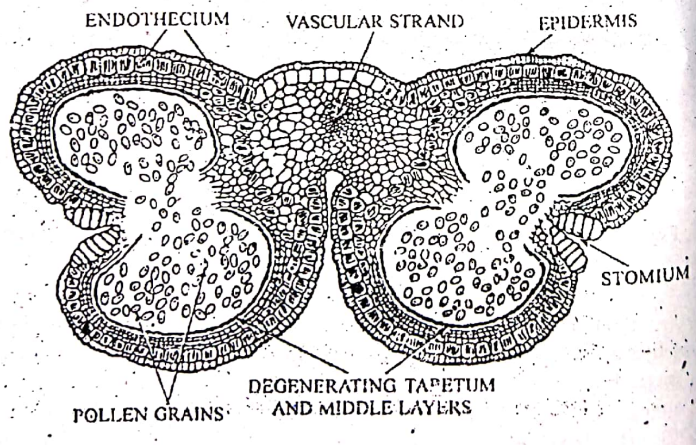

Fig. 25.4

dehiscence the endothecium situated below the epidermis helps mechanically. Opposite the partition between each pair of sporangia (Microsporangia) the cells of the endothecium are thin walled and constitute the **stomium** which marks the line of dehiscence of the mature anther.

Dehiscence of Microsporangium

On the maturation of the anther the middle layers and the tapetum disorganise. Then the fully developed sporangial wall consists of epidermis and endothecium. The sterile partition wall between the two pollen sacs disintegrates and the two pollen sacs of one side unite together forming one compartment. The pollen grains are released out generally through the stomium.

The Pollen Grain

The pollen grains in most plants form a loose dusty power, consisting of a large number of minute grains. This pollen grains vary much in size, form and colour in different plants.

The diameter of the pollen grains varies from 0.025 to 0.15 mm. They are unicilular, spherical, oval or pyramidal in shape. The pollen grains have two distinct walls the **exine** and the **intine**. The intine alone takes part in the formation of the pollen tube.

Q. 26. ***Describe the structure and development of microsporangium in Angiosperms.***

Ans. Stamens are the male reproductive organs of the flower and constitute together the **androecium** of a flower. Actually, they are modified leaves menat to bear male spores (pollen grains) and therefore, are also known as **microsporophylls.** Eaxh stamen consists of **filament, anther** and **connective.** The filament is the slender stalk of the stamen and the anther is the expanded head borne by the filament at its tip. Eaxh anothr consists usually of two lobes connected together by a sort of mid-rib known as the connective. Each lobe contains within it two chambers or loculi, called the **Microsporangia** or **pollen sacs.** Thus there are altogether four loculi in a typical anther. However, in some instances lobe has only one microsporangium (monothecous). Rarely, there may be just one microsporangium per anther (e.g. *Arceuthobium*). Within each pollen sac, there is a fine powdery or granular mass of cells, called the **pollen grains** or **microspores.** These microspores eventualy form the male gametophyte on germination. The stamens arise as a small papillate outgrowth of meristematic cells on the thalamus. The outgrowth due to more growh towards the apex is differentiated into anther and stalk.

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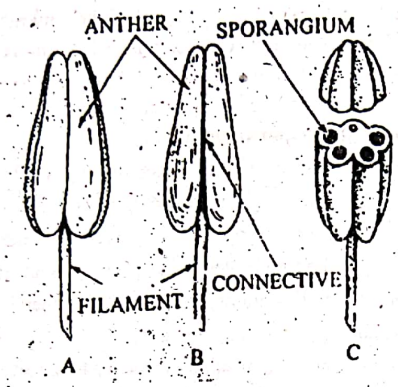

Fig. 26.1. : Different parts of staments (A) Dorsal (B) Ventral (C) T.S. of anther.

Development of Microsporangium

A cross section of a very young anther shows a mass of homogenous meristematic cells surrounded by the epidermis. They young anther soon becomes four lobed and the hypodermal cells become differentiated in each lobe by their larger size, radial elongation and more conspicuous nuclei. These cells form the **archesporium.**

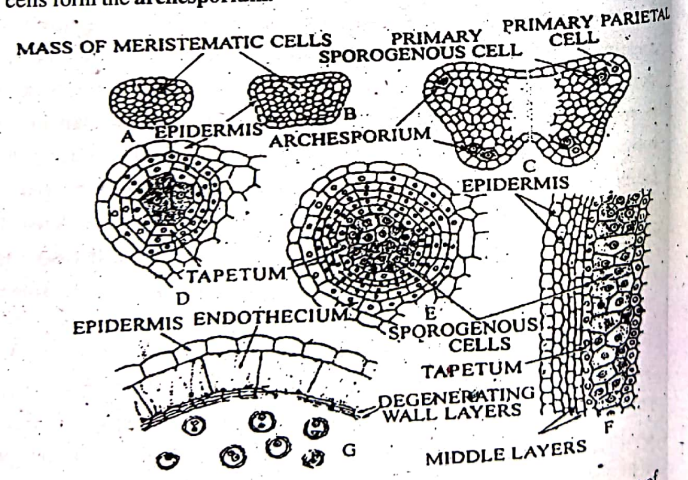

Fig. 26.2. : Microsporagenesis—Different stages of the development of microspore mother cells and wall layers of microsporangium.

The archesporial cells divides to form

(a) A primary parietal layer towards outside.

(b) A primary sporogenous layer towards inside.

The cells of the **primary parietal layer** divide by periclinal and anticlinal walls to give rise to a series of concentric layers usually 3-5 forming the walls of the anther.

The **primary sporogenous cells** either function directly as the spore mother cells or undergo further divisions to form a large number of cells.

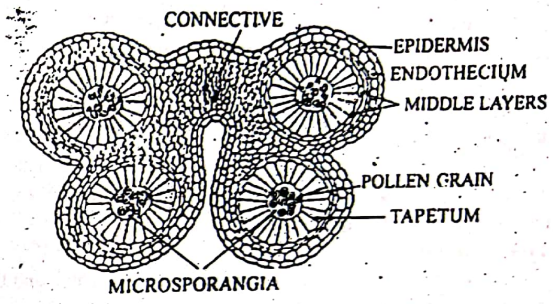

Fig. 26.3. T.S. of mature anther showing microsporangia, wall layers, tapetum and microspares.

The primary parietal layer after periclinal and anticlinal divisions gives rise to 4 wall layers.

The Wall Layers of Microsporangium

(1) The Epidermis—It is the outer most layer of the anther which undergoes anticlinal divisions. Its cells are greatly stretched and flattened, only with-ring of the cells can be seen at maturity.

The epidermal cells may be cutinized or lignified. In xerophytic plants the epidermal cells are stretched too much so that they loose their contact with each other and a maturity only their withering remains are found.

(2) The Endothecium—It is found below the epidermis. Is maximum development is attained at the time when the pollen grains are about to shed. The cells are radially elongated and from their inner walls fibrous bands develop upwards and terminate near the outer wall in each cell. The presence of these bands are responsible for the hygroscopic nature of the endothecial cells which help in the dehiscence of anhers at maturity.

(3) Middle Layers—Next to the endothecium there are usually 1-3 middle layers. All of them become flattened and crushed. The cells of the

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middle layer may store starch or other products whcih are used up at the time of microspore formation.

(4) Tapetum—It is the inner most layer of the wall layers. It is single layered an the tapetal cells are conspicuous filled with dense cytoplasm. The nucli of these cell may divide once or many times. Sometimes these nuclei fuse and form polypoln nuclei, which may divide again. The layer is of considerable physiological significance all the food materials entering into the sporoginous cells, pass through it.

Because of the similarities of appearance and behaviour between the cells of the **tapetum** and the microsporogenous tissue, earlier botanists supposed that the tapetum is derived by a sterilization of the outer sporogenous cells. But developmental studies have confirmed its parietal origin.

However, in some cases the tapetal cells are dimorphic. In Alectra thomsoni, the tapetal cells situated towards the inner side of the anther, are formed from the cells of the connective whereas the rest of the tapetal cells are derived from aparietal layer. In *Antirrhinum majus* the tapetum is formed from the periheral cell of the sporogenous tissue.

Type of Tapetum

There are two main types of behaviour of the tapetum, and they have been divided into the following two types :

1. Glandular type—In this type the dissolution of the cell walls does not take place. The cells remain in their original position throughout the

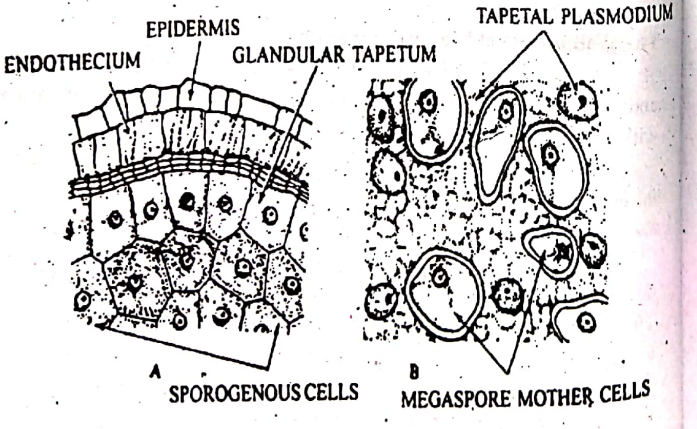

Fig. 26.4. : Types of tapetum. (A) Glandular Type (B) Periplasmodium Type

microspore development. Meanwhile the spaces between the grains are filled

with a homogenous colloidal material which is secreted by the disorganizing protoplast of the tapetal cells. **Echlin** and **Godwin** (1968) have studied this type of tapetum in *Helleborus foetidus* in detail. At the stage of sporogenous tissue the tapetal cells possess mitochondria, plastids, and dictyosomes. During meiosis these bodies increase in size and are found more in cells are nearer the anther cavity. It is presumed that these are secreted by the glandular tapetum. These bodies form the external thickening of the exine of the microspore.

2. Periplasmodium or Amoebold type—It is formed in three stages. The cell walls of the tapetum dissolve and the protoplasmic contents of the cells separate from one another. Thus form the strands and pass between the pollen grains, and only unite together within they reach the loculus. The amoeboid mass thus formed increases in bulk until the species of the loculus are filled. This type of tapetum is found in ***Butomus, Alisma, Typha*** and ***Tradiscantia*** with the help of electron microscope **Mepham** and **Lane** (1969) have reported that in the tapetal cells of *Tradascantia* the cell organelles in periplasmodium undergo re-organization. This break down of the tapetal wall takes place due to the hydrolytic enzymes present in the tapetal cells.

Functions of Tapetum : The tapetum appears to play a significant role in the development of pollen. Its precocious degeneration during premeiotic and meiotic stages or its cellular persistence for unusually long period results in pollen serility. Some of the roles suggesed for the tapetum are :

1. During meiosis it is presumed to be simply transporting the nutrients to the inside of the anther locule since this is the only channel through which material can reach the meiocytes. At this stage the nurients are not derived from the tapetum.

2. Plasmodial cytoplasm derived from the tapetum has callase activity. Shortly before callose degradation starts the cytoplasm of tapetal cells shows cerain vesicles which are probably associated with callase activity.

3. During post-meiotic period tapetum plays an important role in pollen wall formation.

4. Most conspicuous example of transfer of material from tapetum to pollen is of pollen kitt substances and tryphine. Whereas the former appoears to be a complex mixture of hydrophobic lipids and carotenoids, the latter seems to be a complex mixture of hydrophilic substances including proteins.

5. Pollen wall contains proteins derived from the gametophyte as well as the tapetal cells. The proteins of latter origin are present in the spaces and cavities of the exine. These proteins are rapidly released when the pollen grains are moistened and are responsible for the common hay-fever and pollen caused allergy.

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Q. 27. ***Explain the development, types, nature and functions of Endosperm.***

Ans. The endosperm is a tissue full of reserve food material and is very imporant for the growth and development of pre embryo. In gymnosperms, it is the haploid gametophytic tissue which is full of reserve food material while in angiosperms, a new structure the **endosperm** is formed by the fusion of two polar nuclei and one of gametes. Since all the fusing nuclei are generally haploid, the endosperm contains the triploid numebr of chromosomes.

According to **Nawaschin** (1898) the endosperm is a **triploid** structure which is formed after the **double fertilization.** In the endosperm the food is stored which is used at the time of seed germination.

Development of Endosperm

As a rule the development of the endosperm starts before the development of the embryo. The endosperm is formed from the primary endosperm nucleus which is a **triploid** structure (3X). This triploid nucleus undergoes a series of division in the embryo sac and many nuclei are formed. Later on a vacuole appears in the centre and nuclei are migrated towards the periphery of the embryo sac. Later on the wall formation takes place from the periphery towards the centre of the embryo sac and due to centripetal growth the embryo sac is completely filled with compact cellular tissue of endosperm around the embryo.

Types of Endosperm Formation

In Angerosperms there are three general modes of endosperm formation :

(1) Nuclear type Endosperm

(2) Cellular type Endosperm

(3) Helobial type Endosperm

(1) Nuclear type Endosperm—In this type, the endosperm nucleus divides by the process of free nuclear division and many nuclei are formed which round inside the embryo sac. A large vacuole is formed int he centre and these towards perphery. The wall formation starts. It takes place usually of towards the centre of the embryo sac and by further centripetal growth tissu thus formed the embryo sac is filled with a cellular tissue, the Occisionally, as in Coconut, the inerier of the sac is not completely filled cellular tissue. This type of endosperm formation by the process of free called the nuclear type and is quite common.

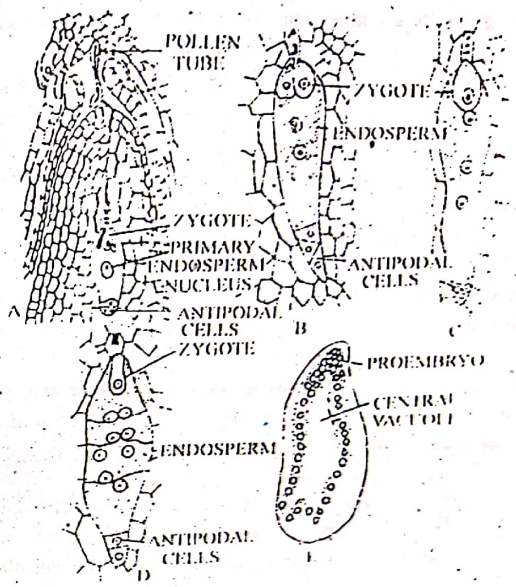

Fig. 27.1. : Nuclear type Endosperm. Various stages of development.

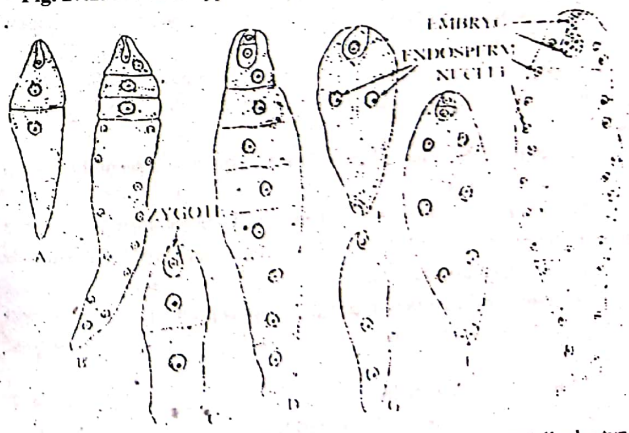

Fig. 27.2. : Development of Endosperm (A-D) Stages of Cellualar type endosperm development (E-H) stages of Helobial type of endosperm development.

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(2) Cellular Type endosperm—When endosperm nucleus divides to from cells and the subsequent divisions of the endsosperm nucleus are immediately follwed by wall formation. This results the formation a mass of cells. Hence the endosperm is *cellular* from the very beginning. This is the cellular type of endosperm formation.

(3) Helobial type endosperm—When the endosperm nucleus divides into two nuclei and a partition wall is laid in between. Later these nuclei divide repeately, but the division in the upper half are comparatively more than the lower one. Hence the *upper portion* consists of several nuclei and the lower of only a few. It is seen that the endsoperm is the tissue formed by the division of endosperm nucleus. This is the helobial type of endosperm formation.

The cells of the endsoperm are filled with food materials absorbed through the placenta. In most of the **monocots** and few **dicots** the embryo remaisn small and the endosperm persists till the germination of the seed, hence the mature seeds are albuminous or endospermic. On the other hand in many dicots the endosperm is used up by the growing embryo which therefore becomes large and hence the mature seed is exalbuminous or non-endospermic. The function of the endosperm is to nourish the developing embryo and in albuminous seeds it noruishes the developing seeding also, during germination.

Morphological Nature of the Endosperm

The following views have been given by different workers to explain is morphological nature.

1. **Hofmeister** (1858), before the discovery of double fertilization has described the endosperm is a **gametophytic** structure whose development is checked.

2. **Lamnnier** (1887) has described the endosperm as a **second embryo** which is actually modified.

3. **Strasburger** (1900) has described it the female gametophyte or the **vegetative tissue.** Its main function is to store large quantitis of food materials for the developing embryo.

4. **Sargant** (1900) has described it as the **sporophytic** tissue or the twin of an embryo as it is formed by the fusion of secondary nucleus with the second male nucleus.

5. **Thomas** (1900) and **Nemec** (1910) has explained that the endosperm is a tissue which has a physiological function also, besides the nutritive function.

6. **Brins** (1904) & **Cooper** (1947) gave a view that it cannot be a sporophytic or a gametophytic tissue in strict sense as it develops after double fertilization and is **triploid** in nature.

7. According to **Haberlandt** (1914) the chief function of endosperm is not that of storage, but the secretion of **diastase** and other enzymes so that the food material stored in the endosperm may be made available to the embryo.

8. Regarding the final fate of the endosperm in some plants like *Ricinus, Phoenix, Triticum* etc. It forms a permanent storage tissue which persists until the germination of the seed, while in *Cucurbita, Arachis, Pisum* the endosperm is used up by the growing embryos and is no longer seen int he mature seeds.

Endosperm Haustoria

In celluler type of endosperm the development of haustoria is either from the chalazal cell or from the micropylar cell or from both. We shall discuss these three case separately.

1. **Chalazal endosperm haustoria.** In **Araceae** and **Nymphaeceae** the primary chalazal cell formed after the first division of the endosperm mother cell undergoes no further divisions and functions directly as a **haustorium.** A similar chalazal haustorium is found in *Balanophora.*

2. **Micropylar endosperm haustoria**— In *Impetieus* the first division of the primary endosperm nucleus gives rise to two chambers a small **micropylar** chamber and large **Chalazal** chamber. The micropylar chamber divides transversely into three cells. The upper most of these containing the Zygote, forms a **giant haustorium** which branches afer some time.

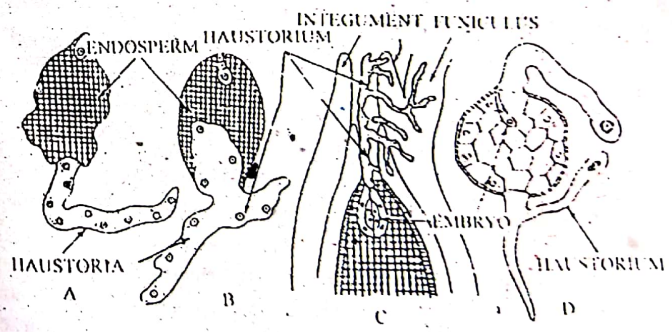

Fig. 27.3. : Types of Endosperm haustoria. (A-B) Chalazal haustoria. (C) Micropylar haustoria. (D) Chalazal and micropylar haustoria.

3. **Micropylar and chalazal endosperm haustoria**—In the genera *Nemophila* belonging to **Boraginaceae** the two equal cells are formed by the first division of the endosperm mother cell. The lower cell functions directly

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as a **chalazal haustorium.** The upper cell divides transversely to give rise to a central cell which is responsible for the main body of the endosperm and a terminal cell which serves as the **micropylar haustorium.**

Q. 28. ***Describe the development of Embryo in Angiosperms.***

Ans. After syngamy (fertilization), the fertilized egg is called as oospore or zygote, after going a period of rest, grows and gives rise to the embryo. During the development of which a series of changes takes place in ovule and result in the seed and fruit formation. In angiosperms each division of embryo development followed by wall formation and not free nuclear as in gymnosperms.

Embryo Development in Dicotyledons :

After the development of endosperm the zygote enlarge and in most of cases except few ones get divided into two by transverse division forming a upper cell towards micropyler end the *basal cell* and lower towards chalanal end the *terminal cell.* The terminal cell known as embryo cell by subsequent divisions term the embryo while basal cell gives rise to suspensor. The basal cell divides by a transver division and terminal cell by a longitudinal division resulting in a 'T' shaped four celled proembryo.

The two upper suspensor cells or four celled proembryo divide transversely and from an filament of six to ten cells, called the *suspensor.* The suspensor cells next to the micropyler end of the embryosac usually falls to divide but enlarge enormously to from a very conspicous *vascular cell.* The suspensor, thus formed elongates and pushes the embryo downwards. The upper most cell of suspensor becomes swollen and elarged and serves the haustorial function.

The lower most cell of the suspensor next to the embryonal cell functions as the *hypophysis cell.* The hypophysis cell divides transversely into two cells and by further division gives to the radicle etc. Side by side the terminal cell of he four celled proembryo also divide by vertical division to the four cell called as *quadrant* stage. This quadrant stage then divides by a transverse wall, so as to give rise eight cells octant to from a middle layer of *periblem* and inner of *plerome.* The lowest cell suspensor, the gypophysis divides to give rise to the dermatogen and periblem of the *radicle.* By further growth and development the embryo at this stage appears somewhat cordate in longitudinal section.

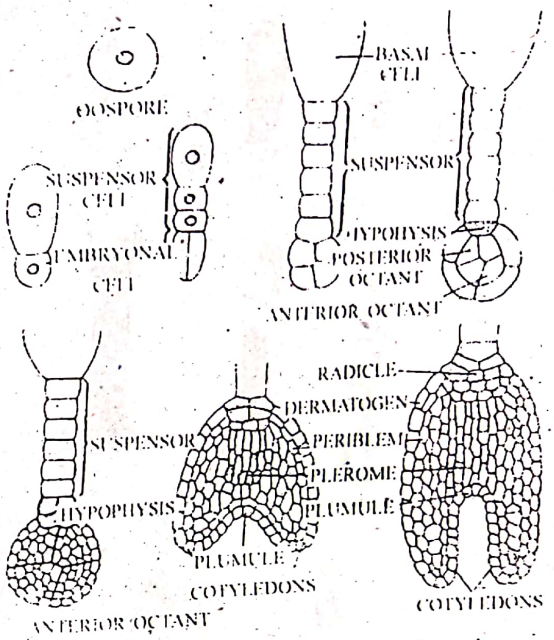

Fig. 28.1. : Showing development of dicot, embryo.

Continued enlargement of hypocotyl and cotyledons result in pronounced curvature of the cotyledons which lie parallel to the axis of the embryo. The mature embryo of most dicto has a pair of lateral cotyledons between the bases of which is situated the rudimentary terminal shoot apex.

The four cells next to hypophysis known as *hypobasal cells* which give rise to hypocotyle except its tip, while the next four cells known as *Epibasal cell* which give rise to plumule and two cotyledons. How all the eight cells of the octant divide by a periclinal divisions forming outer layer of epidermal cell which by one more anticlinal division forms *Dermatogen* and the *inner layer* of cell which divides by a longitudinal divisiosn.

The above said development of dicotembryo is based on the bases of *Capsella bursa pastoris* (Crucifer type) while there may be certain variation, in development of embryo in different plant.

Schnarf (1929) and **Jóhnson** (1945) have recognized five principal type of embryo among the dicotyledons. These may be distinguished from one another as follows :

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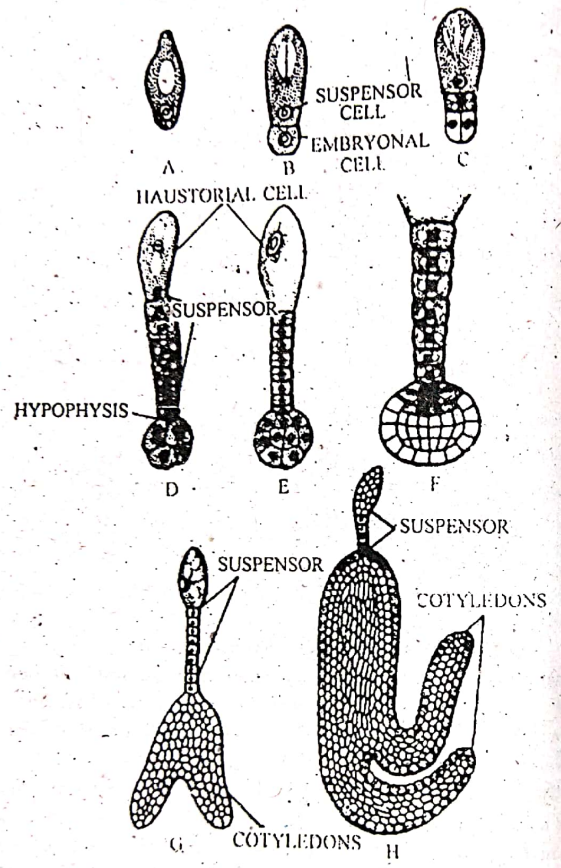

Fig. 28.2. : Dicot Embryo development in Capsella bursa pastoris (dicot).

A. The terminal cell of the two celled proembryo divides by a longitudinal wall :

(1) *Crucifer type or Onagard type*—The basal cell plays only a minor part or none in the subsequent development of embryo.

(2) *Asterad type*—The basal cell and terminal cell both contributed to the development of embryo.

B. The terminal cell of the two celled proembryo divides by a transverse wall :

[a] The basal cell plays only a minor part or none in the subsequent development of embryo.

(3) *Solanand type*—The basal cell usually forms suspensor of two or more cells.

(4) *Caryophyllad type*—The basal cell does not divide further and the suspensor, if present, is always derived from the terminal cell.

(5) *Chenopodial type*—The basal and terminal cell both contribute to the development of embryo.

Q. 29. *What is polyembryony ? Describe various types of polyembryony in Angiosperms.*

Ans. After fertilization, ovules mature into seeds. Normally, a single embryo is present in each seed. But sometimes more than one embryo are present in a seed. This condition is known as **polyembryony.** In nature, there are many plants whose seeds have more than one embryo. But in such plants normally only one embryo matures and the rest degenerate during the course of seed development. Thus the mature seed has only one embryo. Strictly speaking, polyembryony includes all such instances where there is actual occurrence of two or more proembryos or embryos in a developing ovule, irrespective of the fact that only one succeeds to mature and the rest degenerate.

Polyembryony was first time reported by **Antony van Leeuwenhock** in 1719 in the seeds of orange. Since then it has been observed in a large numebr of taxa of angiosperms.

Origin of Polyembryony

On he basis of origin, the following four types of polyembryony have been recognised in angiospersm :

(1) Cleavage polyembryony, which develops due to splitting or cleavage of the proembryo.

(2) Formation of embryos by cells of the embryo sac other than the egg.

(3) Development of more than one embryo sacs within the same ovule.

(4) Activation of some sporophytic cells of the ovule.

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1. Cleavage polyembryony

It is the common and simplest method of the development of more than one embryo in a seed. Two or more embryos are formed in a seed by the cleavage of the zygote or proembryo. Cleavage polyembryony is of widespread occurrence in the gymnosperms, but it is rate in the angiosperms. It was first time observed by **Jeffery** (1895) in *Erythronium americamum* (Liliaceae), and subsequently reported in several other taxa.

Cleavage polyembryony may arise in different ways. In *Erythronium americanum,* the first division of the zygote is normal and as a result a basal and an apical cell are formed. Repeated divisions of the basal cell give rise to an irregular mass of cell which is known as **embryonic mass.** Several cells at the distal end of the embryonic mass develop into separate embryos. This type of cleavage polyembryony has also been reported in *Limnocharis emarginata.* Tulipa gesneriana. Vincetoxicum nigrum. V. officinale and *Habenaria platyphylla.*

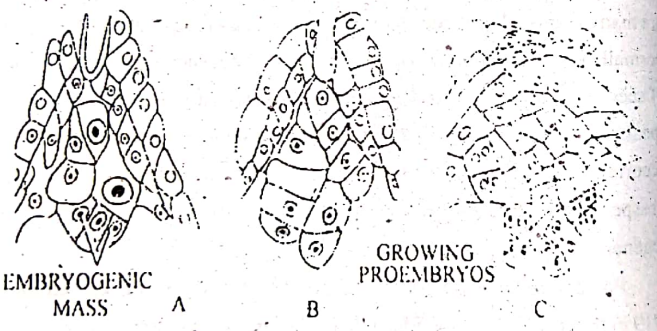

Fig.29.1. A-C. Cleavage polyembryony. A. Embryonic mass formed by the basal cell of the gygote in Erythronium americanum, B-C. **Differentiation of embryos from the cells of the embryonic mass.**

In *Isotoma longiflora* (Campanulaceae) and *Exocarpus* (Santalaceae), additional embryos are developed from the suspensor cells of the proembryo.

Cleavage polyembryony is also fairly common in orchids. In *Eulophia epidendraea,* Swamy (1943) reported three different modes of cleavage polyembryony:

(1) A mass of cell is formed by irregular divisions of the zygote and several cells of this mass present at the chalazal end develop into embryos.

(2) The proembryo gives rise to small bud like outgrowths which develop into supernumerary embryos.

(3) The filamentous proembryo becomes branched, and an embryo develops at the tip of each branch.

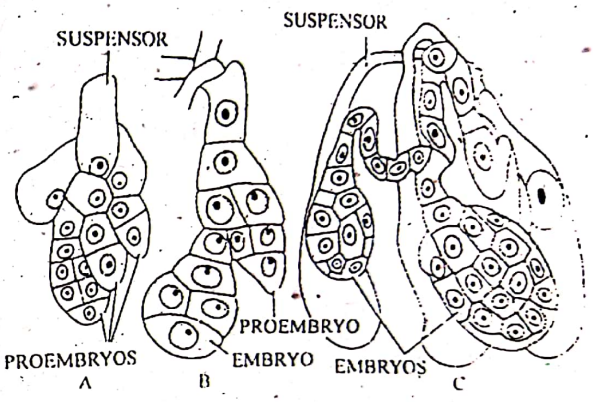

Fig. 29.2. A-C. Cleavage polyembryony : A. Embryonic mass formed by the division of the zygote in Eulophia epidendraea. B. A proembryo formed in addition to the normal embryo. C. Two embryos formed by the splitting of a single embryo.

2. Embryos from cells of the embryo sac other than the egg : In this category the most common source of additional embryos are the synergids. Depending on whether it arises from fertilized synergid or unfertilized synergid, the embryo may be diploid or haploid.

In *Aristolochia bracteata. Poa alpina* and *Sagittaria graminea* besides the egg and the polars, one or both the synergids may get fertilized. This can be brought about either by the entry of more than one polle tube into the embryo sac or by the presence of additional sperms in the same pollen tube. In such a situation the zygotic as well as the synergid embryos are diploid. Embryos arising from unfertilized synergids are known in *Argemone mexicama. Phaseolus vulgaris. etc.* In such cases the zyotic embryo will be distinguished from the synergid embryo (haploid) by its diploid nature.

Formation of embryos from antipodals is rather rare. It has been observed in *Paspalum scrobiculatum. Ulmus americana, U glabra,* etc. The antipodal cells may divide a few times to from proembryo-like structures. Howevêr,

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they fail to grow into an adult embryo and there is no suggestion of antipodals forming germinable embryos.

Reports concerning endosperm cells forming embryos are doubtful. Reinvestigations of all those plants where endosperm embryos were reported at one time have failed to confirm the phenomenon. As such, there is no authentic claim for embryos of endosperm origin.

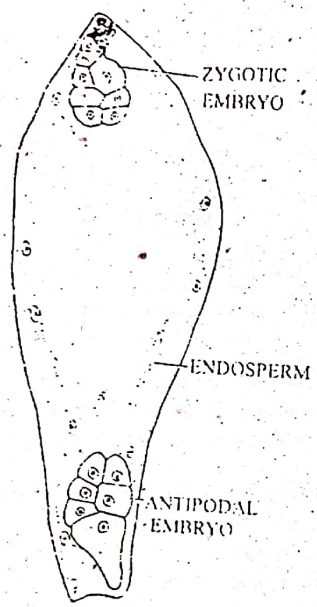

Fig. 29.3. Embryo sac of Ulmus glabra showing zygotic and antipodal embryos (after Ekdahl, 1941)

3. Development of more than one embryo sac in the same ovule : Multiple embryo sacs in an ovule may arise from :

(1) Derivatives of the same megaspore mother cell,

(2) Derivatives of two or more megaspore mother cells, or

(3) Nucellar cells.

Formation of twin embryo sacs within an ovule is known in *Casuarina vanisonfolia. Citrus* and *Poapratensis.* In *Pennisetum ciliare* 22 per cent seeds contain twin embryos. The normal embryo sac develops only up to the 4-

nucleate stage, and the multiple embryos are formed by aposporous embryo sacs.

The member of the family Loranthaceae lack a conventional ovule. Numerous embryo sacs develop concurrently in the same ovary and their tips, carrying the egg apparatus, grow up to vairous heights in the style. After fertilization, the embryos grow downward and enter the composite endosperm (formed as a result of fusion of endosperms of all the embryo sacs in the ovary) in the ovarian cavity. All embryos but one collapse during seed development

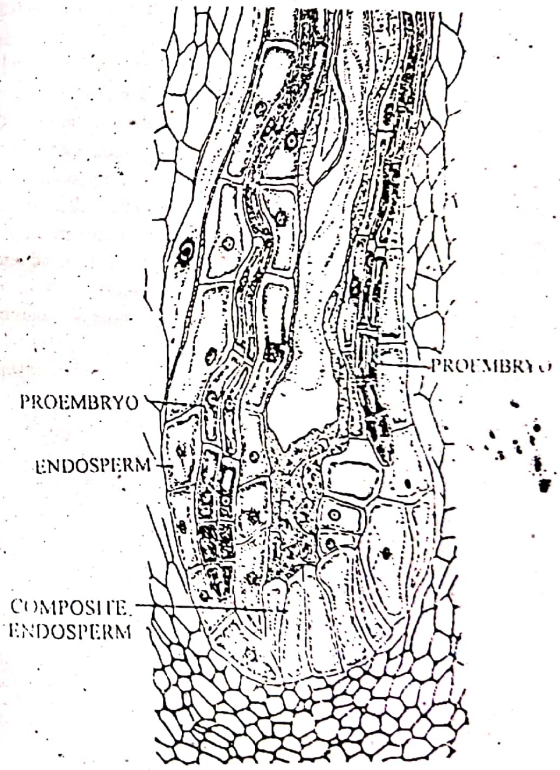

Fig. 29.4. False polyembryony in Dendrophthoe neelgherrensis. Longisection of central part of ovary showing two proembryos embedded in the composite mass of endosperms. (after Naryana, 1954)

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resulting in monoembryonae seeds. Occasionally, however, two or more embryos may mature. In *Scurrula pulverulenta* about 2 per cent seeds show polyembryonate condition (Bhojwani, 1968). In polyembryonate seeds of this parasite there are either two green and fully developed embryos, or there are more than two embryos of which only one is well developed, and the others poorly formed and non-green. The only exception in this family is *Struthanthus vulgaris* which has only one embryo sac and thus does not exhibit polyembryony.

4. Activation of some sporophytic cells of the ovule : The embryos arising from the maternal sporophytic tissue (outside the embryo sac) are called adventive embryos. The only maternal tissues which are known to from adventive embryos are the nucellus and the integuments.

Besides the more popular examples of *Citrus* and *Mangifera,* nucellar polyembryony is known to occur in *Opuntia dillenii, Trillium undidatum,* etc. Some species of *Citrus* are monoembryonate (*C. grandis. C. limon*) while others are polyen bryonate (*C. microcarp, C. reticulata*). Seeds with as many as 40 embryos have been recorded in *C. unshiu.* In polyembryonate species the adventive embryos arise by the proliferation of the nucellar cells. With rare exceptions (*Trillum undulatum*) nucella embryos arise from the micropylar-half of the nucellus. In *Mangifera* the nuclellar cells destined to form adventive embryos can be distinguished from other cells of the cellus by their dense cytoplasm and starchy contents. The inception of nucellar embryos takes place outside the embryo sac but they are gradually pushed into the embryo sac cavity where they divide and differentiate into mature embryos. The adventive

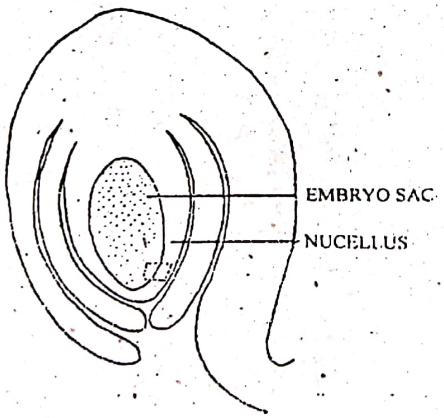

Fig. 29.5. Nucellar polyembryony in Mangifera

embryos do not show synchronous development. A single seed may show embryos at various stages of development. Nucellar embryos can be distinguished from the zygotic embryo by their lateral position in the embryo sac, irregualr shape, and lack of suspensor. In *C. microcarpa, however,* the nucellar embryos possess a distinct suspensor from very early stages. Mostly, for the initiation of nucellar embryos the pollination stimulus seems essential.

Q. 30. ***What do you understand from apomixis ?***

Or, What is apomixis ? How is it different from the normal sexual reproduction ?

Ans. The normal sexual cycle (*amphimixis*) involves two important processes. (a) *Meiosis;* this transforms a diploid sporophytic cell into four haploid gametophytic cells, and (b) *Fertilization;* in which wo haploid gametes of opposite sex fuse reestablishing the diploid sporophytic generation. Thus, in a sexual cycle a diploid generation (sporophytic) alternates with a haploid generation (gametophytic). In pryo sac on the female side and microspore or pollen grain on the male side. The remaining part of the life-cycle belongs to the sporophytic generation.

The plants where the usual sexual reproduction has been completely replaced by a type of asexual reproduction are called apomictic, and the phenomenon is known as **apomixis.** Following **Winkler** (1908), who introduced the ferm, apomixis may be defined as the substitution of the usual sexual reproduction by a form of reproduction which does not involve meiosis and syngamy. A species may include sexually as well as apomictically reproducing individuals. Often a species whcih reproduces sexually in one area behaves apomictically in some other parts of the world. There are two main categories of apomixis.

1. Vegetative reproduction : In this category the plants propagate by a part of their body other than the seed. The structural units employed for this purpose are called propagules.

2. Agamospermy : Plants belonging to this category have retained seed as the agent of propagation but the embryo is formed by some process in which normal meiosis and syngamy have been eliminated. Three different types of agamospermy are recognised :

(i) Adventive embryony : In this type of agamospermy embryos arise directly from the diploid sporophytic cells (nucellus or integuments). The sexual embryo sac develops normally, and the zygotic embryo either degenerates or competes with the apomictic embryos.

(ii) Diplospory : An archesporium differentiates, but the megaspore mother cell (M.M.C.) develops into an unreduced embryo sac (*Aerva*

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tomentosa: Sachar and Murgai, 1959). The embryo is formed by the unfertilized egg (parthenogenesis) or some other cell of the embryo sac (apogamety).

(iii) Apospory : A somatic cell in the nucellus directly forms an unreduced embryo sac, and the diploid egg parthenogenetically develops into embryo. The apomictic embryo sac may develop in addition to the haploid embryo sac derived from a functional MMC. The latter may either degenerate at an early stage or from a sexual embryo after fertilization.

Types of Apomixis

Maheshwari (1950) recognised the following three types of apomixis :

(1) Non-recurrent apomixis

(2) Recurrent apomixis

(3) Adventive apomixis

[1] Non-recurrent apomixis

In this type of apomixis, the megaspore mother cell undergoes normal meiotic division and one of the four megaspores thus formed develops into haploidfemale gametophyte (i.e., embryo sac). However, there is no fertilization and the embryo develops either from the unfertilized egg **(haploid parthenogenesis)** or from some other cell of the embryo sac **(haploid apogamy).** The embryo, thus formed, is naturally haploid.

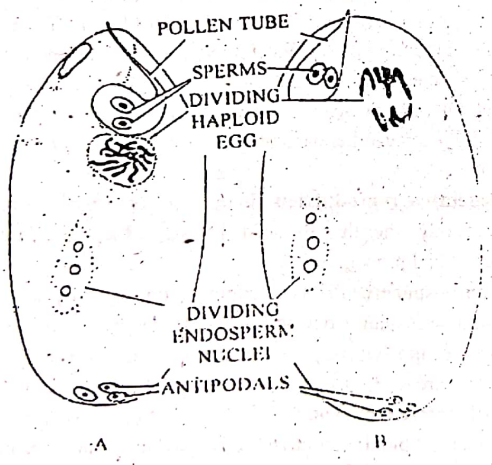

Fig. 30.1. A-B Haploid parthenogenesis in Epipactus larifolia : A. Division in egg before the release of male gametes from the pollen tube . B. Anaphase of dividing egg before the release of male gametes.

1. Haploid parthenogenesis. It is the development of embryo from an unfertilized egg. **Jorgensen** (1928) has shown that haploid parthenogenesis can be induced in some species of *Solanum* by stimulating but not fertilising the egg with the pollen of another species. He observed that when the stigma of *Solaman nigrum* was pollinated with the pollen of *S. luteum*, the male nucleus penetrated the egg but there was no effective nuclear fusion and the male nucleus soon began disintegrate. The egg, however, was activated as if by normal fertilization and an embryo was formed.

According to **Hagerup** (1945), in plans like *Orchis maculata. Epipactus latifolia. Platenthera chlorantha* and *Cephalanthera damasonium* normally pollen tubes enter the ovule and the egg develops into diploid embryo after fertilization, but occasionally pollen tube does not enter the ovule or enters at a time when it is too late for fertilization. In the event of pollen tube not penetrating the embryo sac at all or doing so at a late stage, the egg divides to form haploid embryo without fertilization. According to **Maheshwari** (1950), egg may fail to fertilize due to the following causes : (i) absence of pollen tube, (ii) inability of the tube to discharge its contents, (iii) an insufficient attraction between the male and female nuclei, (iv) an early degeneration of sperms, and (v) maturation of egg and the entrance of male gametes may not be synchronised.

The occurrence of haploid parthenogenesis may be of considerable value in genetical studies as it enables to obtain true breeding homozygous forms.

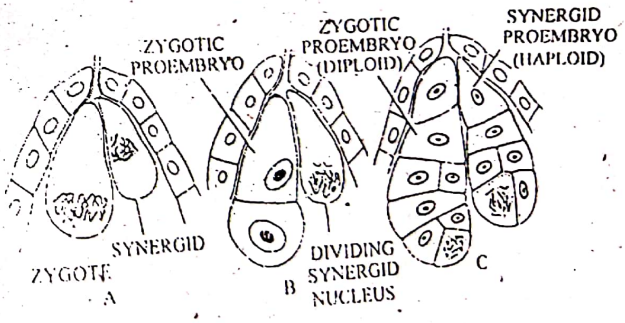

Fig. 30.2. A-C : Haploid apogamy in Lilium : A-B. Dividing egg and synergid; C. Haploid (synergid proembryo) and diploid (zygotic proembryo) proembryos.

2. Haploid apogamy. It is the development of embryo from any cell of the embryo sac apart from the egg. Twin proembryos have been observed in

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Lilium martagon. Bergenia delavayi and *Erythraea centaurium,* one of these embryos develops from the egg by normal fertilization and the other from a stimulated haploid synergid cell. The initial development of the two embryos is closely comparable but the synergid embryo, which is haploid, soon degenerates.

[II] Recurrent apomixis

In recurrent apomixis the nuclei of the embryo sac are usually diploid. Such embryo sacs may arise either from a cell of the archesporium **(generative apospory)** or from some other cell of the nucellus **(somatic apospory).**

1. Generaive apospory. It is the development of diploid embryos from diploid cells of the archesporium. *Parthenium argentatuin*, which has two varieties, is the common example of generative apospory. In one of the varieties (2n = 36) the megaspore mother cell undergoes normal meiotic division and eventually forms the female gametophyte. After syngamy and double fertilization there is coordinated development of the embryo and endosperm. On the other hand, in the othr variey (2n =72), he nucleus of the megaspore mother cell undergoes meiosis but does not give rise to dyad or spore tetrad,

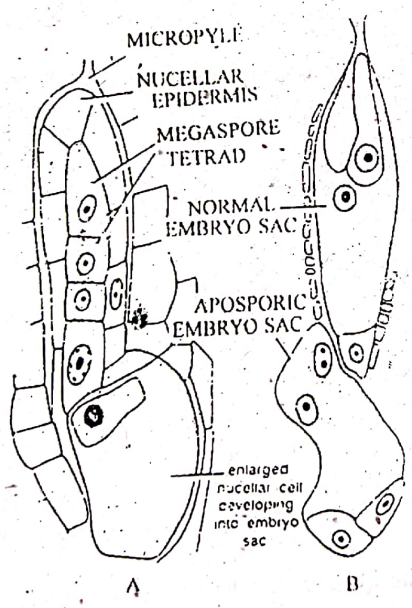

Fig. 30.3. A-B : Development of aposporic embryo sac in Hieracium.

and instead it enlarges and itself functions as an embryo sac. In such embryo sacs the egg develops into embryo without fertilization. In this variety there is only very little or no correlation between the development of embryo and endosperm. Although the development of embryo proceeds normally in the absence of pollination, for the proper development of endosperm pollination is necessary. In the absence of proper development of endosperm, the embryo does not reach maturity.

2. Somatic apospory. The development of diploid embryo sacs from the cell of the nucellus or integument is known as somatic apospory. *Hieracium* is the most common example of somatic apospory. Here the megaspore mother cell goes through usual meiotic division and gives rise to a megaspore tetrad. Soon after the meiotic division is over, a somatic cell situated at the chalazal end of the ovule becomes enlarged and vacuolated. It encroaches upon the megaspore and eventually forms and aposporic embryo sac. As the development of aposporic embryo sac does not involve meiosis. It is diploid. the unfertilized eggs of such embryo sacs give rise to diploid embryos.

Aposporic embryo sac may develop from the cells of the nucellar epidermis and or integuments. Besides *Hieracium,* such embryo sacs have also been observed in *Malus, Crepis, Ranuculus* etc.

[III] Adventive embryony

The development of embryo from any diploid cell of the ovule lying outside the embryo sacs is referred to as adventive embryony. It is also called **sporophytic budding.** In this process there is no alternation of generations.

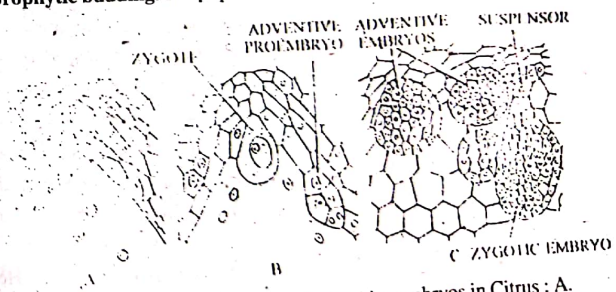

Fig. 30.4. A-C. Development of adventive embryos in Citrus : A. Differentiation of some embryonic cells in the nucellus. B. Development of adventive proembryos. C. Zygotic embryo (with suspensor) and adventive embryos (Without suspensor).

The cells of the nucellus or integuments, forming adventive embryo, become densely protoplasmic and divide actively to form, a small mass of

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meristemtic cells. This tissue mass grows actively, pushes its way into the embryo sac and eventually gives rise to what appears to be a normal embryo. The zygotic as well as the adventive embryo may grow simultaneously in the same embryo sac. The normal (zygotic) embryo has a suspensor, whereas in the nucellar adventive embryo suspensor is absent.

Citrus is the most common example of adventive embryony. As many as ten viable embryos may be found in a single seed of *Citrus*. Adventive embryony is also of common occur rence in the members of the Euphorbiaceae, Cactaceae, Buxaceae, and Orchidaceae.

According to **Maheshwari** (1950), adventive embryos originate from the cells of the nucellus if it is intact. But if the nucellus is desorganised, they may originate in the integument. The development of adventive embryos may take place with or without the stimulus of pollination or fertilization. In *Mangifera indica* and most of the species of *Cirus*. fertilization is necessary for the maturation of adventive embryos. But in *Eugenia jamos* adventive embryos originate without pollination, however, their full development is attained only if he egg is fertilized.

Q. 31. ***Give an account of polyembryony in angiosperms.***

Ans. The occurrence of more than one embryo in the seed is known as polyembryony. This phenomenon was initially discovered in the orange by Leeuwenhoek (1719). Ernst (1918) and Schnarf (1929) have classified it into two types—true and false—depending on whether the embryos arise in the same embryo sac or in different embryo sacs in the ovule. Later on Gustafsson (1946) proposed that the term false polyembryony should be restricted to those cases only where two or more nuclelli, each with its own embryo sac, fuse at an early stage. He included all other types under true polyembryony.

Polyembryony is quite common among conifers (gymnosperms), but many species of both dicotyledons and monocotyledons (angiosperms) exhibit this phenomenon. In the following paragraphs the types of true polyembryony have been considered.

Cleavage polyembryony : This is simplest type of polyembryony. Here the increase in the number of embryos is due to the cleavage of the zygote or embryo. This type of polyembryony is quite common in gymnosperms and sporadic in angiosperms. Jeffrey (1895) reported cleavage polyembryony in Erthyronium americanum. Here the zygote divides to form a small group of cells which continues to increase in volume, and outgrowths are given out at its lower end which function later on as independent embryos. The other examples of cleavage polyembryony are met with in Nymphaea advena, Empertrum nigrum, Nicotiana rustica, Eulophia epidendraea, etc.

Origin of embryos from synergids or antipodal cells : The embryos may also be produced from other parts of the embryo sac such as synergids and antipodal cells. In most cases the synergids become egg-like to form the embryos with or without fertilization. The twin embryos have been recorded in Naias, Tellima, Peltiphyllum and Fragaria, where the fertilization of the synergids by two male gametes is found but endosperm is not formed. Where as in Crepis, Sagittaria, Poa and Aristolochia the fertilization of the egg and one or two synergids is followed by the formation of endosperm. Production of the embryos from antipodal cells is rare. Shattuk (1905 reported such embryos in Ulmus americana. Mauritzon (1933), Fagerlind (1944) have also noted the similar cases in Allium odorum, Sedum fabaria, etc.

Origin of embryos from endosperm : Treub (1898) in Balanophora, Woodworth (1930) in Alnus and others have reported the embryos developed from endosperm. However, Ernst (1913) reported that the embryo develops normally from the egg, embedded in the cellular endosperm and does not develop from the endosperm proper.

Origin of embryos from cell outside embryo sac : The embryos also develop from the cells of the nucellus and integument. Such development of embryos has been reported in Citrus, Syzygium and Mangifera.

Q. 32. ***Describe in detail organisation of mature embryo sac.***

Ans. In majority of angiosperms, the eventual organization of embryo sac shows a uniform pattern, whereas the origin of the mature embryo sac may differ. The Polygonum, Allium, Fritillaria and Adoxa types have similar appearance at the time of fertilization (i.e., three-celled egg apparatus, three antipodal cells, and two polar nuclei). However, in few genera such as Peperomia, Plumbago, Plumbagella, etc. the basic plan of the embryo sac is different.

The egg apparatus : Typically the egg apparatus consists of an egg and two synergids. Usually the synergids are ephermal structures which degenerate and disappear soon after fertilization or sometimes before it. As a rule, each of the synergids is notched and possesses a prominent hook. The nucleus lies in or just below the hook and the lower part of the cell contains a large vacuole. In the egg cell, the nucleus and most of the cytoplasm lie in the lower part of the cell and the vacuole in the upper.

Antipodal cells : The antipodals are usually short-lived. However, they frequently show a considerable increase in size or number. An increase

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in the number of antipodal cells and the number of nuclei per antipodal cell is frequently found in the Compositae. The antipodal cells of some members of Ranunculaceae become greatly enlarged and glandular in appearance.

Polar nuclei : The central portion of the embryo sac contains polar nuclei, and eventually gives rise to the endosperm, and therefore, known as endosperm mother cell usually the two nuclei coming from two different poles are similar in appearance, but sometimes the micropylar polar nucleus is bigger one. The fusion of the polar nuclei may occur either before, or during or sometimes after the entry of the pollen tube inside the embryo sac.

Embryo sac haustoria : In normal cases the general surface of the embryo sac is absorptive in function but in certain cases the ends of the embryo sac show more active growth and convert into haustoria, which absorb the food not only from the nucellus and integuments but also from the placental tissue to which they directly contact. As shown in Fig. 32.1, A, in certain genera of Loranthaceae the embryo sac shows sufficient elongation of the micropylar end where it enters into the tissue of the style and grows into it. In other examples as shown in Fig. 32.1 B, the embryo sac grows downward. Here the chalazal end of the embryo sac acts as haustorium and digests its way through the nucellus.

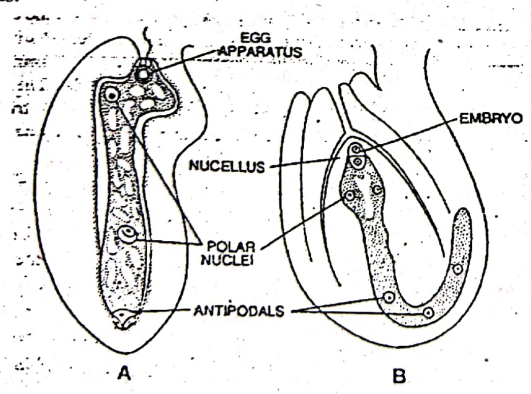

Fig. 32.1 Embryo sac haustoria. A, micropolar end of the embryo sac protrudes out of the ovlule, breaking down completely the nucellus above it; B, the chalazal end of the embryo sac enlarges in size and digests its way through the nucellus and integument.

Q. 33. Describe the development of male gametophyte in Angiosperms.

Ans. The Male Gametophyte :

The development of male gametophyte is uniform in Angiosperms. The microspore or the pollen grain is the first cell of the gametophyte generation. Each microspore is uninucleae the haploid, uncleus being situated nearly in the middle. It has two walls—an inner one which is smooth and called **intine** and the outer one which possesses **germ pors** is known **as exine**. The details of the development of the male gametophyte may be considered under the following heads.

Changes in the Microspore

The first change brough about in the microspore is the appearance of big **vacuole** in the middle. With the appearance of this vacuole the **nucleus** gets pushed to one side of the cell. Here it undergoes division and as a result of this division two cells are formed—one small cell called the **generative cell** and a large **vegetative cell.**

Formation of Vegetaive and Generative Cells

The microspore nucleus divides by a simple division so that a vegetative nucleus and a generative nucleus are formed. After this a delicate cell wall is formed between the vegetative and generative nuclei, which is curved thus a small lenticular generative cell and a large vegetative cell, are formed.

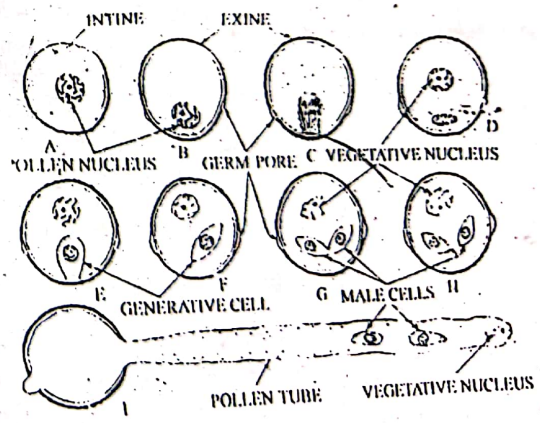

Fig. 33.1. : Pollen grain and charges in its structure after development of male gametophyte.

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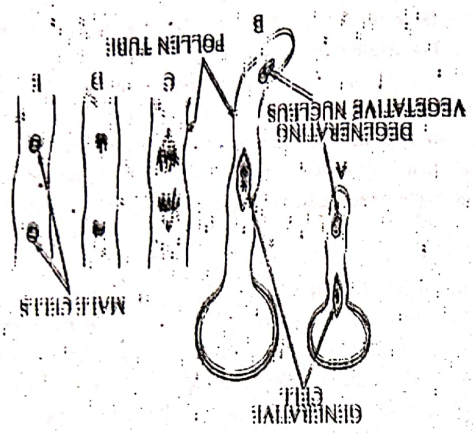

Fig. 33.2 : Division of the generative cell in pollen tube and formation of male nuclei.

Generative Cell—The shape of the generative cell is considerably variable, it may eliptical, lenticular, spindle shaped or sometimes quite long as in *Cuscuta*. The generative cell divides once again to give rise two **Male gametes.** The division of the generative cell may take place either in the pollen grain or in the pollen tube, so the pollen grains at the time of shedding may be two celled or three celled. Sometimes both the conditions may be found in the same genus as in Nicotiana and the cleistogamous flowers of *Viola*.

Division of the Generative Nucleus—The generative nucleus may divide either (a) before the pollen grain germinates, or (b) in the pollen tube. The later is the commoner case. Sometimes it occurs on the stigma before the pollen tube begins to grow. In extreme ase i.e., *Euphorbia* the division of the generative cell was postponed until the pollen tube had actually entered the embryo sac.

As far as present evidence goes it may therefore be concluded that the division of the generative cell whether it takes place in pollen grain or in pollen occur in a regular fashion.

Male Cells or Nuclei

Formerly it was believed that whenever the division of generative cell occurs is the pollen grain it is followed by the formation of sperm cells, but if it takes place in the pollen tube only nuclei are formed. Recent work has shown that in all cases the male gametes are definite cell and the cytoplasmic sheath persists throughout their course in the pollen tube. (**Schnarf** 1941).

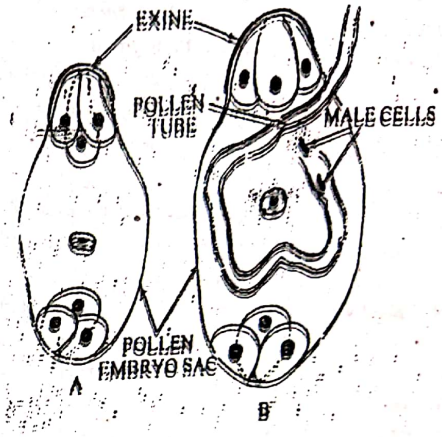

Fig. 33.3. : Hyacinthus orientalis.

Vegetative cell—It is differentiated from the generative cell by the presence of food materials in the form of starch and fat. It was previously considered that the vegetative nucleus (often called tube nucleus) is directing the growth of the pollen tube. Present evidence seems to indicate that the functional importance of the vegetative or tube nucleus is greatly lost. The vegetative nucleus is regarded as a vestigial structure in the growth of the pollen tube (**Sulta** 1937).

Abnormal Type of Male Gametophyte or Pollen Embryo Sac

Generally the pollen grain has 2 or 3 nuclei but in some cases the pollen grains develop into eight nucleate embryo sac like structures.

In *Hyacinthus orientalls*, Nemec in 1898 has reported this type of eight nucleate **embryo** sac like pollen grain, hence is called **Nemec Phenomenon.** He has explained that the generative cell degenerates and the vegetative cell divides three times so that eight nuclei are formed. According to **Stow** (1934) the **microspore nucleus** divides thrice to form eight nuclei. This abnormal behaviour results due to the secretion of **Necrohormone** by the dead pollen grains, which are mixed with the functional one. The pollen grains are 3-4 times enlarged and the three nuclei out of eight, give rise to an **egg apparatus** at the exine, while the other three nuclei give rise to **antipodals** at the opposite end. The remaining two nuclei fuse in the centre and form the secondary nucleus.

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Q. 34. ***With the help of suitable diagrams describe the development of polygonum type of embryo sac or female gametophyte.***

Ans. The Female Gametophyte or Embryo sac

The functional megaspore is haploid and is the starting point of the female gametophyte. In angiosperm the megaspore nucleus does not proceed beyond 8 nucleate stage during the development of embryo sac or the female gametophyte.

The embryo sacs are classified on two main characters. The first is the number of megaspores taking part in the formation of the embryo sac and second is the number of nuclei in the mature sac.

Prof. Maheshwari (1950)has classified the development of embryo sacs into the following three classes, depending upon the number of megaspore cells and megaspore nuclei taking part in the development.

1. Monosporic embryo sac

2. Bisporic embryo sacs.

3. Terasporic embryo sacs

The main classes of the embryo sacs constitute the following ten types depending of the number of the nuclei.

Prof. Maheshwari (1950) has classified the various types of embryo sac in Angiosperms on the basis of their development.

(1) Monosporic (When four megaspores are formed)
- (A) Eight nucleate embryo sac— *Polygonum type*
- (B) Four nucleate embryo sac— *Oenothera type*

(2) Bisporic (When two megaspores are formed)
- Eight nucleate embryo sac— *Allium type*

(3) Terasporic (When megaspores are not formed only nuclei are formed in megaspore mother cell)
- (A) Eight nucleate embryo sac—
  - (i) *Adoxa type*
  - (ii) *Fritillaria type*
  - (iii) *Plumbago type*
- (B) Four nucleate embryo sac—
  - (i) *Plumbegella type*
- (C) Sixteen nucleate embryo sac—
  - (i) *Drusa type*
  - (ii) *Penaea type*
  - (iii) *Pepromia type*

(1) Monosporic Embryo Sac

The Polygonum type : Eight Nucleate embryo sac—This is the normal type of female gametophyte or embryo sac. Here the **Megaspore mother cell**

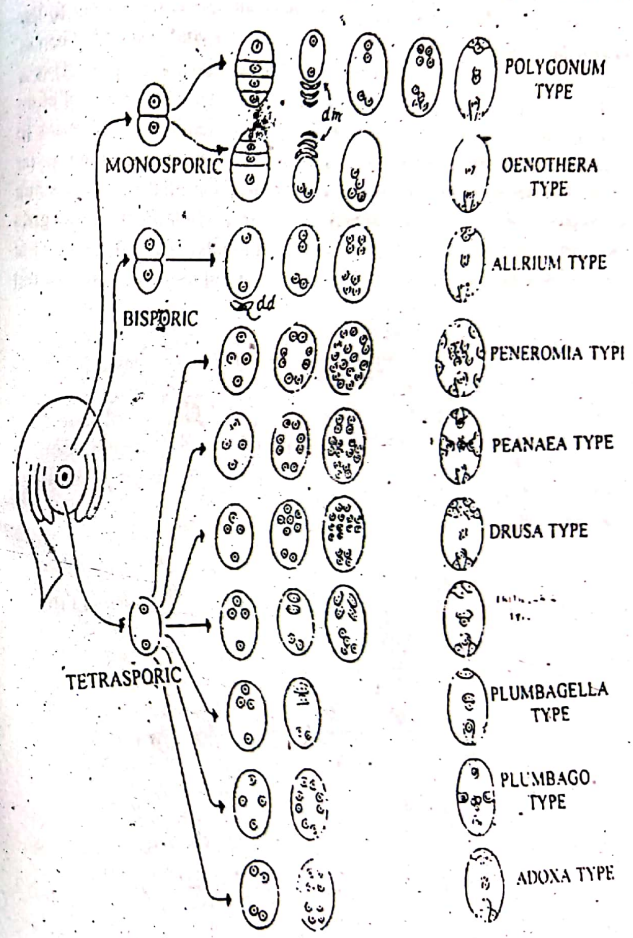

Fig. 34.1. : Development of Monosporic, Bisporic, Tetrasporic embryo sacs in different plant.

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nucleus after dividing mitoically forms four haploid megaspores which are arranged in a linear tetrad of which the lower most (chalazal) **Megaspore** is functional. The nucleus of the functional megaspore divides by simple division into two nuclei. Thee two nuclei move to opposite poles, one going to the **micropylar end** of the embryo sac and the other to the **chalazal end.** Then as a result of second nuclear division two nuclei are formed at each pole. This is followed by the third nuclear division which results in the formation of eight nuclei, four at each pole. During these changes the embryo sac increases in size and a big vacuole is formed in its centre. Of the four nuclei at the micropylar pole, three are organised into the **egg apparatus,** the central cell of the egg apparatus is the egg, ovum or **oosphere.** The other two cells are the **synergids** which help in the process of fertilization. The **synergids** are usually somewhat pear shaped. Similarly three nuclei at the **chalazal end** form three thin walled

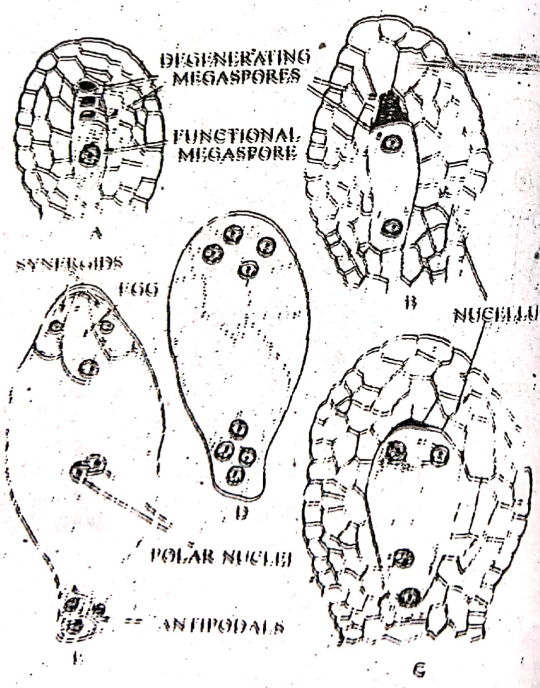

Fig. 34.2. : Polygonum type of embryo sac ; Stages showing the development of monosporic, 8 nucleate embryo sac.

antipodal cells. Now one free nucleus remains at each pole. These two nucle i.e., one **micropylar polar nucleus** and one **antipdial polar nucleus** move to the centre of the embryo sac and fuse threre to form the **secondary nucleus** which therefore, is diploid. Sometimes the two polar nuclei remain lying side by side and fuse together at the time of fertilization. The name *Polygonum* has been given to it because it was first described in *P. divaricatum* by **Strasburger** (1879).

Structure of the Normal Embryo Sac

The embryo sac is a larger structure which is surrounded by cellulose wall. It contains eight nuclei of similar size with cytoplasm. At a later stage, these eight nuclei are arranged in two groups of four nuclei at opposite poles an vacuole appears in the centre containing sap. Near the approach of fertilization the central vacuole is divided into many small vacuoles and the secondary cytoplasm is accumulated around the two polar nuclei which have been fused in the centre of the sac. The cytoplasm may contain a large number of starch grains which disappear after fertilization.

The embryo sac enlarges in size either by the destruction and absorption of some of the inner layers of nucellar tissue or by destroying the entire nucellus so that the embryo sac wall becomes very closer to the inner integument and it is generally cuticularized. After the formation of eight nuclei they take their characteristic position the wall formation takes place at both ends simultaneously but where there is any difference it has always been seen that the antipodal cells are formed before the micropylar cells.

(1) The Synergids—Normally two synergids are found on either side of the egg, they are similar in size. The name synergids has been given by **Strasburger** as they help in fertilization, after which they are of no use and disappear. In exceptional cases they disappear before fertilization. The pointed ends of the synetgids are attached to the apex of the embryo sac and their lower rounded ends hang into the space of the embryo sac. Their walls are made up of cellulose.

The structure of the synergid has been known since 1856 but its function is not yet well understood. However the synergid helps in performing the following functions :

1. It protects the cell from bursting at the upper end during fertilization.
2. The pollen tube generally enters through it.
3. It has a secretory function in attracting the pollen tube during its entrance.
4. It is quite tough and durable as it remains upto the last.
5. The lower large, founded end of each synergid contains a large vacuole which also plays an important part in fertilization.

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Sometimes the synergids show abnormal behaviour also.

(2) The egg (oosphere)—Its position is really lateral to the synergids but it hangs down below them so as to appear that the oosphere cell is attached to the base of the synerged cells. The oosphere contains a **female generative cell.** The nature of the oosphere membrane is of great interest. The upper part is made of cellulose which remais in contact with the synergids, the lower free, portion seems to have only plasmatic membrane until after fertilization.

In the cytoplasm of oosphere apart from the nucleus, certain plastids are also found which manufacture starch found in it. The nucleus of the oosphere is larger than the nuclei of the synergids. The nucleolus is also larger in size, it begins to increase in volume as the time of fertilization approaches.

As the maturation of the oosphere nucleus increass its stain ability decreases. The chromatin first takes a prophase like structure, then there is a discharge of nuclei acid from the chromosomes, which take on a chromomeric structure. The chromomeres later on also disappear and ultimately the nucleus loses its all chromatinity. This condition of the nucleus remains untill the nuclear fusion takes place.

(3) The polar nuclei—In the eight nucleate embryo sac one nucleus at each end i.e. micropylar and chalazal of the embryo sac migrates towards the centre of the sac. These nuclei unite either before fusing or after the entry of the pollen tube into the sac and the product of their union is called as the **secondary** embyro sac nucleus, the central nucleus or the primary **endosperm nucleus.** This endosperm nucleus and the cytoplasm around it is known as the primordium of the endosperm.

In majority of Angiosperms fusion of the polar nuclei takes place before fertilization. The indosperm nucleus moves very close beneath the oosphere or it remains in the center, it never moves towards the antipodal cells.

(4) The Antipodal Cells—Normally there are three antipodals though there are few exceptions. They are separated by thin cell walls which are first plasmatic later becomes cellulosic.

In much narrow embryo sacs whose growth is restricted the number of antipodal cells may be reduced or less than three. Sometimes abnormal enlargement of the antipodal cells takes place eg. ***Crocus, Kris*** etc.

Their main function is to supply nutrition to the embryo sac. In he growing embryo sac the nucellus is destroyed and the inner integument is also used up. The main supply of water and food materials come from the chalaza and enter the sac at the antipodal end. Sometimes the antipodal cells become aggressive and develop into chalazal haustoria.

(2) Bisporic Embryo Sac

Allium Type : Eight Nucleate Embryo Sac

Strasburger (1979) has described bisporic embryo sac development in *Allium fistulosum*. megaspore mother cell divides to form two dyad cell, Either the lower (Allium) or th upper cell (Scilla) of this dyad may develope. The nucleus divides to form 2,4 and then 8 nuclei, which are arranged normally in the embryo sac. This type of embryo sac is found in several monocot families e.g. **Liliaceae, Antaryllidacease** and **Orchidaceae.** Among dicots it is found in Podostemaceae, Balanophoraceae and Loranthaceae.

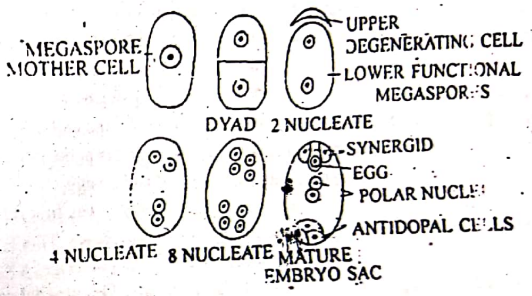

Fig. 34.3. : Allium type : Development stages of Bisporic, 8-nucleate embryo sac.

(3) Tetrasporeic Embryo Sac

Adoxa Type : Eight Nucleate Embryo Sac

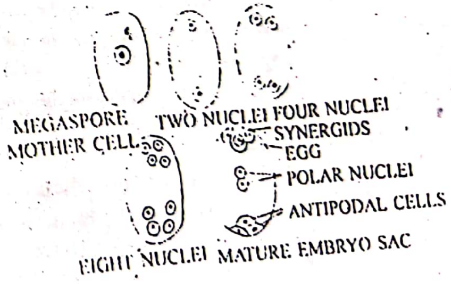

Fig. 34.4. Adoxa type embryo sac : Developmental stages of Tetrasporic, 8-nucleate embryo sac.

This type of the development of embryo sac has been studied by **Jonsson** (1879-1880) in *Adoxa-moschatellina*. The nucleus of the megaspore mother

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cell divides twice to give four megaspore nuclei, without cell division and these divide again once to form eight nuclei which are normally arranged. In this eight nucleate of embryo sac is very less commonly found only in **Adoxa** and **sumbucus** and in some species of **Ulmus Tulipa** and **Erythronum.**

Penaea type—This type of embryo-sac was first reported by **Stephans** (1909) in *Penaea, Sarcocolla* and *Brachyosiphon*. Like Peperomia type, the embryo-sac is 16-nucleate; the nuclei lie in four distinct quadrat arranged cross wise one each at the ends of the embryo-sac and two on sides. Now from each quadrat, a nucleus moves in the centre to form a polar nucleus where all the four polar nuclei fuse together to form a secondary nucleus. The three nuclei situated at the micropylar end organise into an egg and two synergids.

Such a type of embryo-sac is know to occur in many families, like Malpighiaceae, Combretaceae, Euphorbiaceae, etc., **Maheshwari** and **Johri** (1941) found in ***Acalypha indica*** that there are four pairs instead of triads as normally observed. There are 8 polar nuclei in the centre and at the micropylar end, the egg apparatus consists of only one synergid and an egg.

Drusa type—This type of embryo sac development was first reported by **Hokasson** (1923) in ***Drusa oppositifolia*** (Fam. Apiaceae). This type of embryo-sac is also 16-nucleate. The mature embryo-sac comprises a normal egg apparatus (1 egg, 2 synergids), two polar nuclei and 11 antipodal cells.

Q. 35. What do you understand by the term fertilization ? Explain it detail.

Ans. Fertilization : The transference of the pollen from the anther to the receptive stigma, whether of the same flower or of a different flower is known as **pollination.** After the pollination the next stage is the germination of the pollen to form a pollen tube in which the male gametes are carried to the female gametophyte (embryo sac). Fertilization is the final phase of this biological process where the male and female gametes fuse with one another giving rise to the embryo.

Germination of the Pollen Grain

The content of the pollen is a male gametophyte. The pollen grain is very sensitive to moisture. It absorbs the liquid from the moist surface of the stigma and swells up. The pollen tube comes out due to the protrusion of the intine through the **Germpore**. Then the pollen grain has germinated, the pollen tube penetrates the stigma through the stigmatic papillae. The tubes pass down into the stylar canal, keeping contact with its walls. The penetration of the pollen tube in the stylar region is due to the presence of moisture in it.

Generally the stigmatic surface is papillose and the pollen grains germinate between them. The germination occurs with extraordinary rapidity, in a few

minutes in most cases. The cells of the stigma have the appearance of secretory cells, dense cytoplasm and large nuclei they are closely jointed and may be easily separated. The pollen tubes enter always them and not into them. Some stigmas have a continuous cutiele in which pollen tubes penetrated by **enzyme** action. Many stigmas are covered by the mucilage and oily substances in which pollen grains are bathed, thes esubstances are protective in function rather than of chemical importance for the pollen grains.

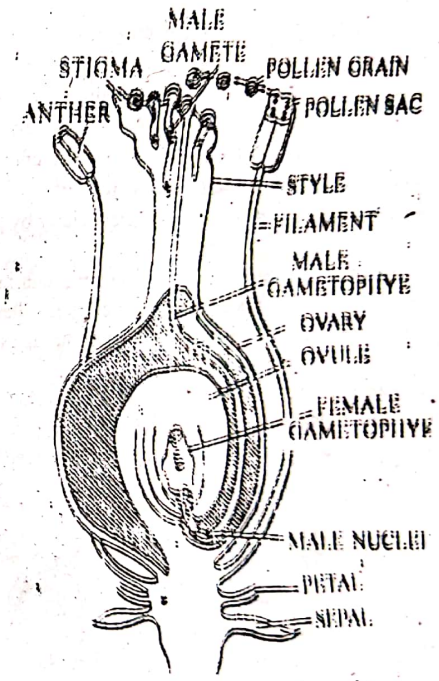

Fig. 35.1. L.S. of flower showing process of Fertilization.

Usually a single pollen tube develops from each pollen grain, but several pollen tubes have also been reported to develop from the pollen grain in a few members of **Cucurbitaceae**. The pollen tube now grows through the style towards the ovule. The **tube nucleus** usually moves to the erminal end of the pollen tube. By this time the **generative cell** also divides and forms two small male gametes. Mostly the pollen tube enters into the ovule through the micropyle and reaches near the embryo sac.

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Growth and structure of pollen tube

The pollen tube emerge at the germ pore on pollen grain and almost the entire contents of grain move upto the tube. In a growing tube most of the cytoplasm is confined to the apical region and a large vacuole fills the grain and the order region of tube. To restrict the cytoplasm to apical region, a series of callose plugs are formed at regular distance behind the tip.

The pollen tube wall is made of cellulose and pectin.

Path of Pollen tube

In angiosperms the pollen grains through the process of pollination get deposited on the stigma. As we know that the ovules are present inside the ovary, so pollen grain directly can not come in direct touch of female gametophyte or embryo sac. The time taken by the pollen grain to germinate on stigma is variable from few minutes to few days in different plants.

Passage of Pollen Tube or Entry of pallen tube in Ovule

The pollen tube enters into the ovule in different plants by the following methods :

1. Porogamy—Usually the pollen tube enters through the **micropyle** and reaches the embryo sac. This normal mode of entry is called **porogamy**. Sometimes in few cases the pollen tubes do not enter through the micropyle and the method is called as **aporogamy.**

2. Chalazogamy—It was discovered by **Treub** (1891) in *Casuarina.* The pollen tube enters the **chalaza** through the funicle and sends out in the chalaza many irregular branches and then makes its way upwards in embryo sacs.

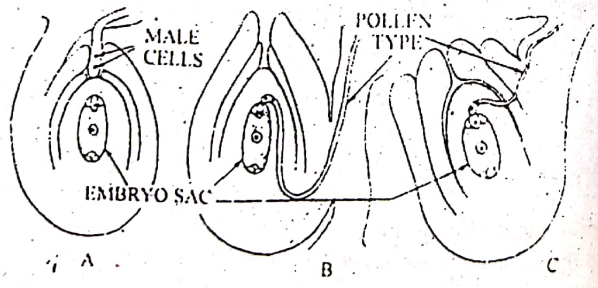

Fig. 35.2. Entry of pollen tube into the ovule.
(A) Porogamy (B) Chalazogamy (C) mesogamy.

3. Mesogamy—It is found in *Populus.* The pollen tube enters the ovule through the side of the **integument** nearest the placenta, curves round the channel of the micropyle and reaches the embryo sac through the nucellus.

Entry of Pollen Tube in Embryo Sac

After pentrating the wall of the embryo sac the pollen tube may pass either any of the following ways depending on the type of plants.

(i) Between the **egg** and one **synergid** e.g. *Fagopyrum*

(ii) Directly into a **synergid** e.g. *Oxalis.*

(iii) Between the egg and one **synergid** e.g. *Fagopyrum*

Discharge of Male Nuclei

In *Crepis capillaris* the tip of the pollen tube becomes wedged in between the egg and the polar fusion nucleus (secondary nucleus) so that both the male nuclei are discharged in close proximity to their mates. **Fagerlind** *(1939)* noted some embryo sacs of *Pipromia* in which the tip of the tube had divided into two short branches one of which was directed towards the **egg. Cooper** *(1940,* 41, 46) refers to similar bifurcation of the tip of the pollen tube in *Portulaca and Petunia,* one branch becoming closer to the egg and the other extending in the direction of the **polar nuclei,** and suggests that the two male nuclei reach their destinations by way of three separate branches.

Fusion of Male and Female Nuclei

The form of the male gamete may be spherical or ellipsoidal. In *Scilla* sp. the male nucleus fertilizes the **egg,** is smaller than the other male nucleus which is fusing with the **polar nuclei.**

Gerassimove (1933) has studied the gametic fusion in *Crepis capillaris.* At the time of i s approach to the eggf nucleus, the **male** nucleus has the appearance of continuous thread rolled into a ball, which soon begins to unwind and spread out with is entire surface adjacent to the nuclear membrane of the egg. It then gradually immerses itself within the eggf nucleus. Meanwhile

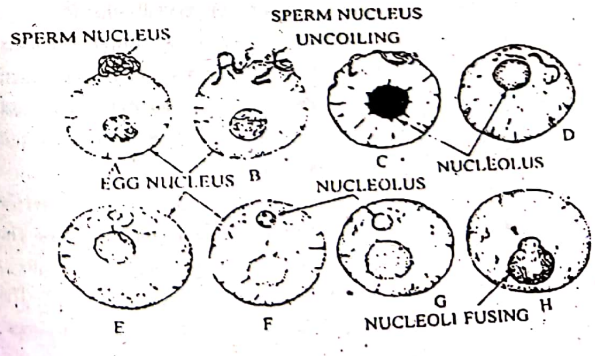

Fig. 35.3. : Synagamy : Fuison of male and female nuclei.

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nucleous. Meanwhile nucleous arises from it. At the sametime the body of the sperm become more porous and breaks up lengthwise losing its continuity. Very soon he male chromatin becomes indistinguishable from the female and it is only he presence of the two **nucleoli** which serve too distinguish the fertilized egg from the unfertilized egg. Finally the male nucleolus increases in size and fuses with the female nucleolus thus closing the phenomenon of sexual union of the nuclei.

The fusion of the second sperm with the second sperm with the secondary nucleus takes place in very much the same way.

The fusion of one of the male gametes with the ovum results in the formation of the embryo; while the fusion of the other male gamete with the secondary nucleus results in the formation of the endosperm and not in the formation of a siser embryo as expected. It has been suggested that the presence of a second polar nucleus might be a disturbing element and as such the endosperm nucleus develops as a result of triple fusion into the endosperm instead of growing into an embryo.

Q. 36. *Describe the development of Embryo in Angiosperms.*

Ans. After syngamy (fertilization), the fertilized egg is called as oospore or zygote, after going a period of rest, grows and gives rise to the embryo. During the development of which a series of changes takes place in ovule and result in the seed and fruit formation. In angiosperms each division of embryo development followed by wall formation and not free nuclear as in gymnosperms.

Embryo Development in Dicotyledons :

After the development of endosperm the zygote enlarge and in most of cases except few ones get divided into two by transverse division forming a upper cell towards micropyler end the *basal cell* and lower towards chalanal end the *terminal cell.* The terminal cell known as embryo cell by subsequent divisions term the embryo while basal cell gives rise to suspensor. The basal cell divides by a transver division and terminal cell by a longitudinal division resulting in a 'T' shaped four celled proembryo.

The two upper suspensor cells or four celled proembryo divide transversely and from an filament of six to ten cells, called the *suspensor.* The suspensor cells next to the micropyler end of the embryosae usually falls to divide but enlarge enormously to from a very conspicous *vasicular cell.* The suspensor, thus formed elongates and pushes the embryo downwards. The upper most cell of suspensor becomes swollen and elarged and serves the haustorial function.

The lower most cell of the suspensor next to the embryonal cell functions as the *hypophysis cell.* The hypophysis cell divides transversely into two cells and by further division gives to the radicle etc. Side by side the terminal cell of he four celled proembryo also divide by vertical division to the four cell called as *quadrant* stage. This quadrant stage then divides by a transverse wall, so as to give rise eight cells octant to from a middle layer of *periblem* and inner of *plerome.* The lowest cell suspensor, the gypophysis divides to give rise to the dermatogen and periblem of the *radicle.* By further growth and development the embryo at this stage appears somewhat cordate in longitudinal section.

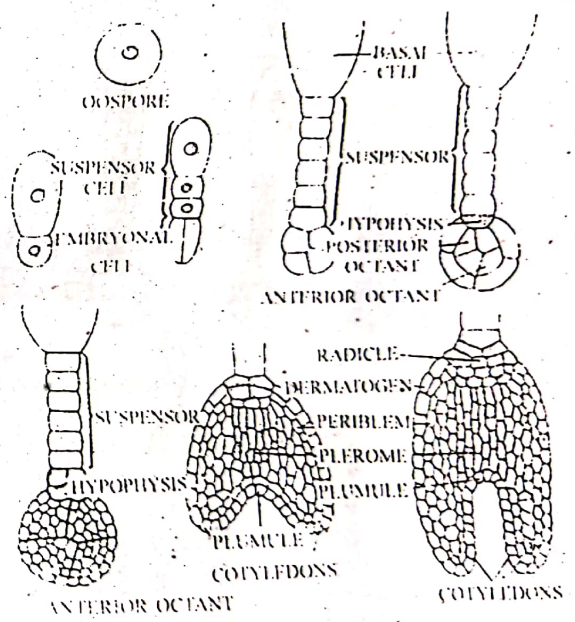

Fig. 36.1. : Showing development of dicot, embryo.

Continued enlargement of hypocotyl and cotyledons result in pronounced curvature of the cotyledons which lie parallel to the axis of the embryo. The mature embryo of most dicto has a pair of lateral cotyledons between the bases of which is situated the rudimentary terminal shoot apex.

The four cells next to hypophysis known as *hypobasal cells* which give rise to hypocotyle except its tip, while the next four cells known as *Epibasal cell* which give rise to plumule and two cotyledons. How all the eight cells of

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the octant divide by a periclinal divisions forming outer layer of epidermal cell which by one more anticlinal division forms *Dermatogen* and the *inner layer* of cell which divides by a longitudinal divisiosn.

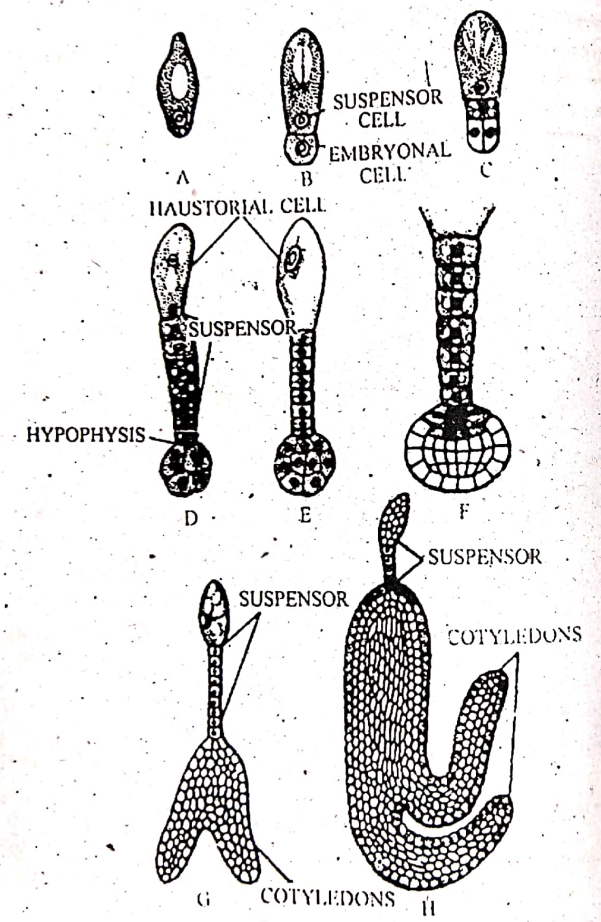

Fig. 36.2. : Dicot Embryo development in Capsella bursa pastoris (dicot).

The above said development of dicotembryo is based on the bases of *Capsella bursa pastoris* (Crucifer type) while there may be certain variation in development of embryo in different plant.

Schnarf (1929) and **Johnson** (1945) have recognized five principal type of embryo among the dicotyledons. These may be distinguished from one another as follows :

A. The terminal cell of the two celled proembryo divides by a longitudinal wall :

(1) *Crucifer type or Onagard type*—The basal cell plays only a minor part or none in the subsequent development of embryo.

(2) *Asterad type*—The basal cell and terminal cell both contributed to the development of embryo.

B. The terminal cell of the two celled proembryo divides by a transverse wall :

[a] The basal cell plays only a minor part or none in the subsequent development of embryo.

(3) *Solanand type*—The basal cell usually forms suspensor of two or more cells.

(4) *Caryophyllad type*—The basal cell does not divide further and the suspensor, if present, is always derived from the terminal cell.

(5) *Chenopodial type*—The basal and terminal cell both contribute to the development of embryo.

Q. 37. *Describe the Role of Embryology in Taxonomy.*

Ans. Role of Embryology : Taxonomy of plants has been based on their morphological characters. This has resulted in the assemblage of sdome plants having remote relationships to the same family or different families of the same order. Such assemblage remained controversial for long and only after their embryological aspects were studied in detail that their correct systematic position could be found out. Some specific examples are as follows :

Genus *Trapa* was for long included in the family **Onagraceae**. It is now excluded from this family and placed in a separate family **Trapaceae** as *T rapa* differed embryologically from other members included in the family **Onagraceae**. While members of Onagraceae are characterised by monosporic 4-nucleate embryo sac, *Trapa* develops monosporic 8-nucleate embryo sac, much resembling the Polygonum type.

Butomus was formerly included in the family **Butomaceae** along with *Butomopsis*, *Limnocharis* and *Hydrocleis* even though *Butomus* differed from the other three genera in morphological characters. *Butomopsis*, *Limnocharis* and *Hydrocleis* showed morphological similarities with the members of the family **Alismaceae**. Inclusion of *Butomus* in the family **Butomaceae** was, therefore, doubted. This doubt was cleared off after detailed study of the embryo-

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logical characters of all these members. *Butomus* develops monosporic 8-nucleate embryo sac, anatropous ovule and straight embryo while the other three general develop bisporic, 5-to 6-nucleate embryo sac, campylotropous ovule and curved embryo.

They, thus, showed similarities with the embryological characters of the members of the family, **Alismaceae**. This resulted in the reservation of the family **Butomaceae** for *Butomus* and the rest three genera have been included in **Alismaceae**.

Controversy regarding the systematic position of *Callitriche* was solved by **Jorgensen** (1925) on the basis of its embryological studies. *Callitriche* wass formerly included in the family **Euphorbiaceae** which was later invalidated on account of the possession of tenuinucellar tapetum, unitemgic and anatropous ovule, cellular endosperm and characteristic micropylar and chalazal haustoria by this genus. It has been given a separate family rank, Callitrichaceae.

The subfamilies **Loranthoideae** and Viscoideae, included in the family **Loranthaceae**, now enjoy the ranks of families, Loranthaceae and Viscaceae after being justified on the basis of embryological studies conducted by **Johri** and his co-workers in Delhi.

Sphenoclea has been retained in its original order Campanulales and in or near to the family **Campanulaceae** on embryological evidences put forward by **Subramanayam (1950). Aryshaw** (1948) has suggested its separation from Campanulales and assignment to the family **Sphenocleaceae** between **Phytolacaceae** and **Primulaceae**.

Likewise, *Exocarpus*, which was once considered by **Gagnepain Boureau** (1944, 47) to be a member of gymnosperms on the basis of their observations for the presence of naked ovule, articulated pedicel and pollen chamber, was later on proved to belong to angiosperms on embryological evidences by Manais Ram (1957).

Controversies regarding the systematic positions of *Paeonia*, *Pentaphragma* and many other plants have similarly been solved with the help of embryo logical studies.

Embryological Features used in Sorting out the Taxonomical Problem :

(1) Tapetum of anther—Glandular or amoeboid.

(2) Cytokinesis in the PMC—Sucessive or simultaneous. Whether the laying down of wall is due to furrowing or by the formation of cell plates.

(3) Development and organization of pollens—Number, size and shape; colpate, acolpate, porate or non-porate; number and position of the germ pores and furrows, if any. Nature of exine, i.e., smooth, spinous, spinulose, echinate, verucose, grooved or with any other sculpture. Site of the farmation of generative cell and male gamete.

(4) Development and st ructure of ovule—Presence or absence of vascular supply in the integruments; whether the micropyle is formed by the inner integment or outer integument, or by both. Presence or absence of obturator.

(5) Form and extent of the nucellus—Whether it is broad and massive or thin and ephimeral, i.e., crassinucellate or tenuinucellate.

(6) Place of the origin of integuments—Whether it is adjacent to the nucellar tip or its base; presence or absence of hypostage and epistage; persistent or deciduous nature of nucellus.

(7) Origin and extent of the sporogenous tissue in ovule—Whether the archesporium unicellular or multicellular, presence or absence of wall layers; presence or absence of periclinal division in the nucellar epidermis.

(8) Megasporogenesis and development of embryo sac—Shape of the megaspore tetrad; position of functioning megaspore. Whether the sac is monosporic, bisporic or tetrasporic; nuclear division during megagametogenesis and differentition of egg.

(9) Form and organization of mature sac—Shape of the sac along with the number and distribution of its nuclei; whether the synergids and antiopodal cells are present or deciduous; increase in the number of antipodal cells; formation of the sac haustoria or caeca.

(10) Fertilization—Path of the entry of pollen tube; interval between polination and fertilization; simple or branched nature of pollen tube.

(11) Endosperm—Cellular or helobial type, orientation of the first wall in the cellular type; presence or absence of haustoria; nature and position of haustoria. Whether the seed is endospermic or non-endosapermic.

(12) Embryo—Relation of the proembryonal cells to the body of embryo; presence of absence of suspensor.

(13) Certain anomalies—Parthenogenesis, apogamous or adventive embryony, or any kind of polyembryony.

Q. 38. ***Explain about the Female Gametphyte.***

Ans. Principal types of female gametophyte (embryo sac) : Principal types of embryosac are three—(a) Monosporic, (b) Bisporic and (c) Tetrasporic.

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MONOSPORIC EMBRYO SAC. Megaspore mother cell divides meiotically, forms four **megaspores,** three of which degenerate and the embryo sac is formed by the single remaining megaspore. Usually the chalazal megaspore forms the embryo sac. In some cases the micropylar megaspore forms it.

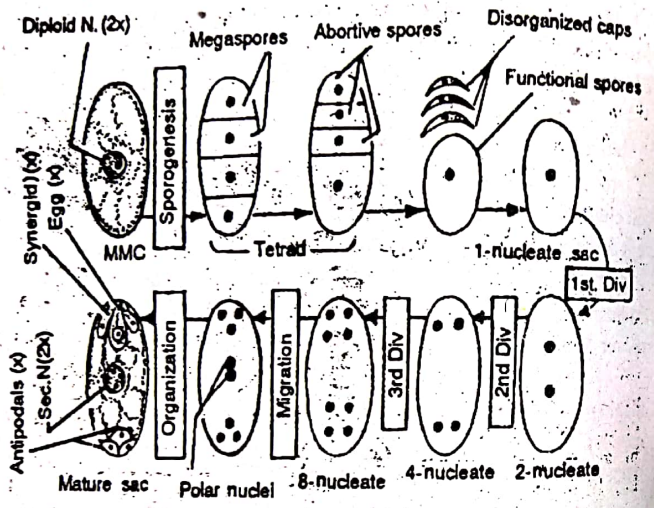

Fig. 38.1. Monosporic type : Steps in the development of 8-nucleate embryo sac in *Polygonum.*

Monosporic embryo sacs are again of two types—(a) 8-nucleate Polygonum type and (b) 4-nucleate Oenothera type.

(a) Polygonum type : Chalazal megaspore forms the embryo sac. Megaspore nucleus divides by three divisions to form eight nuclei, four at each pole. Three nuclei at the micropylar end form the egg apparatus and a polar nucleus. Three nuclei at the chalazal end form antipodal cells and a polar nucleus. The polar nuclei meet in the centre to form the secondary nucleus, e.g., *Polygonum divaricatum* (Fig. 38.1).

Embryo sac with more than eight nuclei or less than eight nuclei has also been reported in this type.

Link : More than eight nuclei may occur due to (1) fusion of two embryo sacs; (2) migration of the nuclei from the nucellar cells, (3) secondary divisions of any of the first-formed eight nuclei.

Less than eight nuclei may be due to (1) early degeneration of antipodals, (2) suppression of the divisions in the chalazal nuclei.

(b) Oenothera type : Embryo sac in this type is formed from the micropylar megaspore. Megaspore nucleus divides twice only and forms four nuclei, which get arranged in the micropylar end of the embryo sac. Three of the nuclei form the egg apparatus while the fourth nucleus forms the single polar nucleus and so a single nucleate secondary nucleus. There is no formation of antipodal cell or the lower polar nucleus (Fig. 38.2).

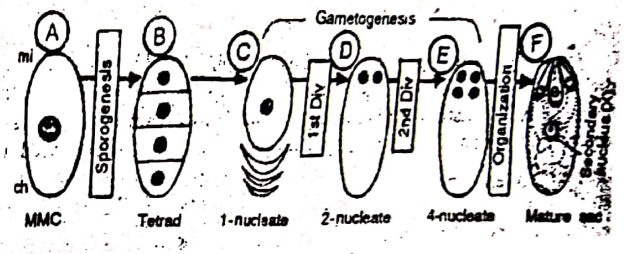

Fig. 38.2. Monosporic type : Steps in teh development of 4-nucleate sac in *Oenothers* (mi = micropylar end, ch = chalazal end).

In this case also, but very rarely, more than four nuclei (*Anogra pallida*) or less than four nuclei (*Hartmannia teraptera*) in the embryo sac have been reported.

Oenothera type of embryo sac is reported in all the members of the family **Onagraceae** except *Trapa*, which shows Polygonium type of embryo sac.

BISPORICEMBRYO SAC : By the first division, megaspore mother cell forms two diad cells, one of which degenerates while the other divides to form two nuclei without a wall formation in between. The embryo sac formed by the diad ell is a bisporic embryo sac. The two nuclei divide twice and form eight nuclei in two groups of four each at either pole. Three nuclei out of four at the micropylar end form an egg apparatus and the fourth one a polar nucleus. Likewise, three nuclei at the chalazal end form antipodal cells and the fourth one a polar nucleus. The two polar nuclei meet to form the secondary nucleus.

There are two types of bisporic embryo sac : (a) 8-nucleate Allium type and (b) 8-nucleate Endymion type. Developmental of embryo sac in both the

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types is similar with the only difference that Allium type is formed by the chalazal diad and Endymion type by the micropylar diad (Fig. 38.3).

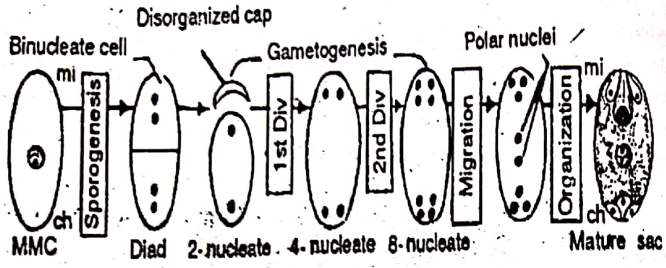

Fig. 38.3. Bisporic type : Steps in the development of 8-nucleate embryo sac in *Allium*

Variation : Embryo sac may have reduced number of nuclei at the chalazal end. Example of Allium type—*Allium fistulosum.*

TETRASPORIC EMBRYO SAC : Megaspore mother cell divides by meiosis, four nuclei being formed without wall formation. Embryo sac formed from such megaspore mother cell is called tetrasporic embryo sac. The organised embryo sac may be 4-, 8- or 16-nucleate.

(a) 16-nucleate Peperomia type : Four nuclei, formed by the reduction division in the megaspore mother cell, undergo two more divisions and form

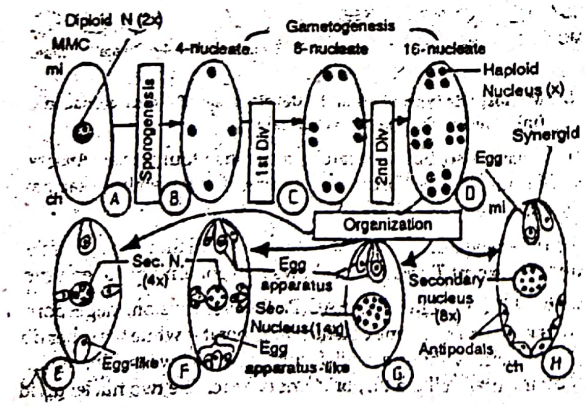

Fig. 38.4. Tranportic types

16 nuclei evenly distributed in teh embryo sac. Fully organised embryo sac consists of an egg and a synergied at the micropylar end, six antipodal cells at the chalazal end and eight nuclei migrating to the centre to form 8n secondary nucleus, e.g., *Peperomia pellucida* (Fig. 38.4).

Variation : Secondary nucleus is formed by the fusion of 14 nuclei in *Peperomia hispidula* and by the fusion of seven nuclei in *Cunna.*

(b) 16-nucleat Pinea type : Four nuclei are formed by the division of the megaspore mother cell as described above, followed by two more divisions resulting in the formation of 16 nuclei. These are arranged in four groups with four nuclei in each, one at the micropylar end, one at the chalazal end and two at th two peripheral sides. Egg apparatus is formed by theree nuclei at the micropylar end. One nucleus form each group migrates to the centre and there the nuclei fuse to form 4n secondary nucleus. Ther remaining nuclei cut out into cells at chalazal end and on the two sides (Fig. 38.4). Example—*Pinaea, Brachysiphon* and *Sarcocolla.*

(c) 16-nucleate Drusa type : Four nuclei are formed by the division of the megaspore mother cell in the usual way. Arrangement of these four nuclei is in 1 + 3 ratio, one at the micropylar end and three at the chalazal end. All the four nuclei divide twice to form 16 nuclei, showing 4 + 12 arrangments. Three, out of four nuclei at the micropylar end, form an egg apparatus while the fourth one forms the polar nucleus. Eleven nuclei at the chalazal end form antipodal cells and the remaining one forms the lower polar nucleus. The two polar nuclei meet to form the secondary nucleus (Fig. 38.5). Example—*Drusa oppositifolia.*

Variation : 8-nucleate embryo sac is reported in *Ulmus americanum.*

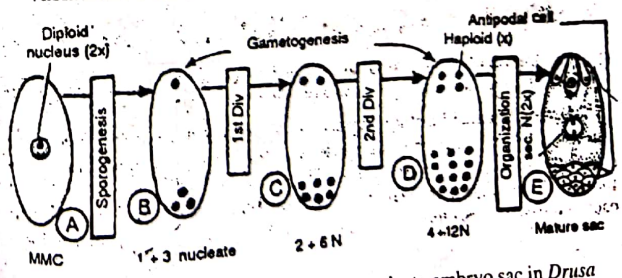

Fig. 38.5. Developmental steps of 16-nucleate embryo sac in *Drusa*

(d) 8-nucleate Fritillaria type : Megaspore mother cell by meiotic division forms four nuclei, one at the micropylar end and three at the chalazal end.

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Three nuclei at the chalazal end unite to form a triploid nucleus. These two nuclei (one haploid at the micropylar end and the other tripoloid at the chalazal end) divide twice to form eight nuclei, four haploid nuclei at the micropylar end and four triploid nuclei at the chalazal end. Egg apparatus is formed by three of the haploid nulcei at the micropylar end, and three triploid nuclei at the chalazal end form the antipodal cells. One haploid and one tripoloid polar nuclei meet in the centre to form 4n secondary nucleus (Fig. 6). Example—*Fritillaria, Lillium.*

(e) 4-nucleate Plumbagella type : The process of the division of the megaspore mother cell, migration of one micropylar nucleus to the chalazal end and fusion of the three nuclei at the chalzal end to form a triploid nucleus are similar to those of Fritillaria type. However, the two nuclei divide only once and form a four nucleate embryo sac. One haploid nucleus at teh micropylar end forms the egg, one triploid nucleus at the chalazal end forms the antipodal cell and the remaining two (one haploid and the other triploid) become the polar nuclei and meet to form the secondary nucleus (Fig. 38.6).

Example—*Plumbagella micrantha.*

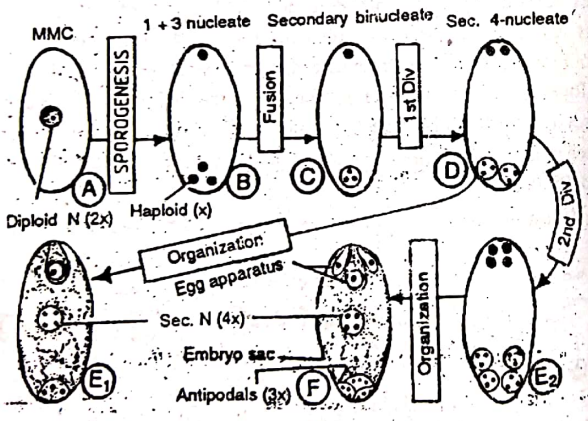

Fig. 38.6. Tetrasporic type (1 + 3) : Developmental steps of sac in two genera (A- D & E_1) *Plumbagella* and (A-F) *Fritillaria* or *Lilium.*

(f) 8-nnucleate Plumbago type : Four megaspore nuclei are formed in the usual way. Arrangement—one nucleus at the micropylar end, one at the chalazal end and two on the two sides. These four nuclei divide once again and

form eight nuclei, two at the micropylar end, two at the chalazal end and two each at the two sides. One nucleus from each group meets in the centre to form the 4n secondary nucleus. One nucleus at the micropylar end forms the eggs, there being no synergid, and the remaining three nuclei either cut out into cells or degenerate (Fig. 38.4). Example—*Plumbago capensis.*

(g) 8-nucleate Adoxa type : Four megaspore nuclei divide once forming eight nuclei, four at each pole. Three nuclei at the micropylar end form the egg apparatus, three at the chalazal end form the antipodal cells. The two polar nuclei meet to form secondary nucleus (Fig. 38.7). Example—*Adoxa moschatellina.*

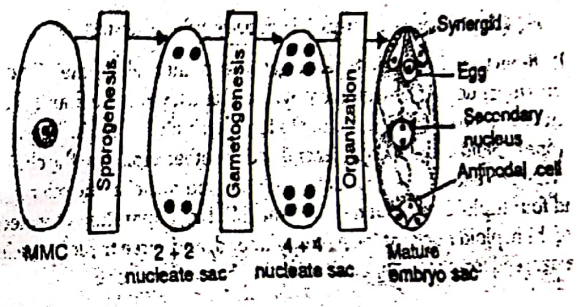

Fig. 38. 7. Tetraporic type : Steps in the development of 8-nucleate sac in Adoxa.

Q. 39. *What is double fertilization ? Give its significance.*

Ans. After the pollen tube has discharged its contents into the embryo sac, one male gamete (nucleus) fuses with the **egg** (syngamy) and the other male gamete (nucleus) fuses with the two **polar nuclei** forming triploid nucleus. Two nuclei are fused at the time of the development of the embryo sac to form **secondary nucleus** and the 3rd is male gamete fuses with secondary nucleus which is now known as **endosperm nucleus** and developes into the endosperm. As the fertilization is twice the process is known as **Double fertilization** *i.e.* (1) Fisrt fusion when the 2 polar nuclei are fused in the centre of the embryo sac. (2) Later on the 2nd male gamete fuses with this diploid secondary nucleus, results the second fusion or double fertilization.

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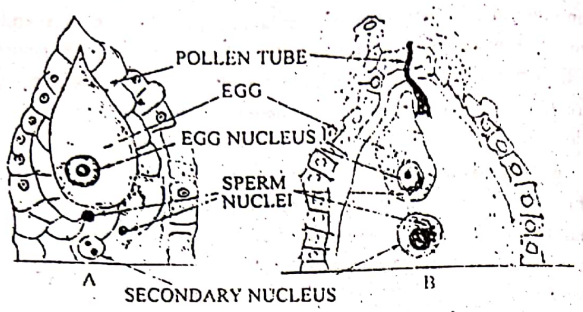

Fig. 39.1. : Fertilization and double fertilization (A) Two male nuclei discharged in embryo sac. (B) Male nucleus + Egg = Fertilization, Male nucleus + Secondary nucleus = Double fertilization

In Angiosperms he **endosperm** is a new sructure formed in most cases as a result of the fusion of two polar nuclei and the second male nucleus as a result of **double fertilization,** which was established as a normal occurrence by **Nawaschin** (1898) and **Guignard** (1899). The actual union is also called **triple fusion,** as three nuclei are involved (i.e. 2 polar nuclei and male nucleus). In some embryo sacs, the number of polar nuclei may be much more than two. The endosperm is the main source of food for developing embryo.

There are only two families of Angiosperms in which endosperm development is absent, e.g. **Orchidaceae** and **Podostemaceae.**

Significance of double fertilization.

Double fertilization is a process in which second male gamete fuses with two polar nuclei forming a triploid structure. This process was discovered by **Nawaschin** (1898) and **Guignard** (1899) have established it as of common occurrence in Angiosperms.

The endosperm formation result due to double fertilization and the embryo derives is nourishment for growth from endosperm, therefore the process of double fertilization is of great significance. It is also clear from reports of several scientist that the needs formed either by syngamy without triple fusion or by triple fusion without syngamy are nonviable. Thus for the production of viable seeds in angiosperm the process of double fertilizaion is most essential.

Q. 40. ***Explain the seed antomy.***

Ans. In most embryos,t he procambium is commonly found in some isolated areas and a few mature protoxylem and protophloem cells may be present. The anatomy of the embryo proper is the histology of meristems.

Anatomy of the cotyledon—The traces of the cotyledon vary in number. Comonly only two traces are found in the lower taxa of both monocotyledons and dicotyledons. Four is a frequent numebr, with transition to three by the fusion of the middle pair. Three is also common with the strong cental bundle sometimes double. The largé numbers of traces are probable uncommon (*e.g. Canna* and some Araceae). When four traces are present, the two median traces lie close together. The Iridaceae have a median trace, simple or double, with one or two pairs of laterals. The Araceae have one to many traces. The liliaceae have all stages in the origin of an old number of traces—two traces, four traces, a double traces, a median trace with one or more pairs of laterals. Odd numebrs result from the fusion of two or more traces. Number, positon and fusion of traces coincide with those of leaf traces. A single trace is characteristic of highly specialized cotyledons. In many taxa, commonly, he lateral bundles are free distally and with the median bundle, formed a three veined cotyledon, he two free laterals become major bundles in he anatomy of many specialized cotyledons.

The characteristic feature of many monocotyledons is the presence of two strong lateral traces, that supply the sides of the sheathing leaf base. The median vein that supplies the cotyledon tip, bends downward to the scutellum. The lateral veins continue upward in the sheathing wings, or rarely they also continue downward to the scutellum. The tip of the median bundle, remained unbranched in small and cylindrical forms, but becomes branched in large forms.

In most cotyledons which possess two of three free tracs, all the vascular bundles continue as veins towards the tip. In the downbent cotyldom where the tip has been transformed into a scutelum, all the bundles may continue in he cutellum, but usually only the median bundle extends to it; the lateral bundles are shorter and their distal parts recurve below the point of down bending. The down bent cotyledons which show the prominent sheath as a part of the cotyledon, the lateral bundles are also prominent.

An even numbr of traces in the cotyledons of angiosperms denotes the primitive condition. The primitive taxa (*e.g.*, Ranales, Liliales, Helobiales) have cotyledons with two strong traces, often with pairs of lateral traces. In most gymnosperms even numbered traces are characteristic. In angiosperms the odd-numbered traces are derived from even-numbered traces.

The number of cotyledonary traces is fairly constant in families. For example, two traces are commonly found in most of the lower monocotyledonous families. The Liliaceae have two in the lower tribes: two,

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four and six in others. The Zingiberaceae have two traces. The Amaryllidaceae have two; the Iridaceae, one two or three. The Araceae have one to several and the Cannaceae have several. Among dicotyledons the woody Ranales have two traces. The vascular system of the cotyledon of monocots has two major bundles or two with additional vascular bundles. The cotyledons of dicot have commonly three major bundles.

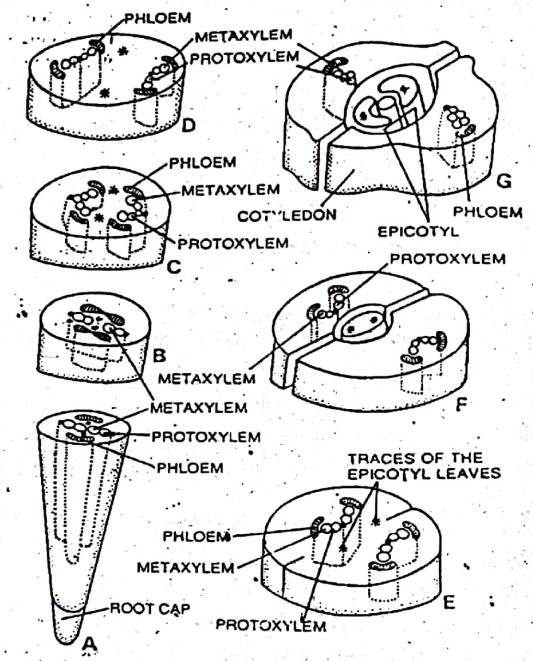

Fig. 40.1. : Anatomy of seedling of dicotyledon (*Beta vulgaris*). A—E, diagram showing the connection between the root and the cotyledons in he transition region. Description in text. (After Esau)

Anatomy of mesocotyl—The mesocotyl is a compound structure which consists of the hypocotyl and the adnate part of the cotyledon. It contains the vascular tissues of the stele of the hypocotyl and one or more vascular bundles of the cotyledon. The external and internal effect of adnation of the cotyledon neck to hypocotyl is frequently found. External evidence of the fusion is the presnce, in some genera, of a longitudianal ridge on the axis of embryo; internal evidence is the presence of a vascular bundle running longitudinal in the cortex of hypocotyl. he superfluous bundle belongs to the down bent adnate neck of

the cotyledon that makes the vascular supply of the scutellum, the median bundle of the cotyledon continued downward from the point of downbending of the cotyledon neck. The vascular supply of the scutellum thus follows a roundabout course, like an inverted V. With the result of the bending downward of the tip of the cotyledon, the adnate vascular bundles, as seen in cross sections of the mesocotyl, are inverted, the xylem external to the phloem.

When the downrunning bundle of the cotyledon is merged with the vascular tissue of the hypocotyl, its free tip, which supplies the scutellum, is attached at the base of hypocotyl. In a monocotyledonous embryo (*e.g. Zea mays*) the scutellum represents the cotyledon; the mesocotyl represents the first internode of stem; the coleoptile represents the first leaf; and the hypocotyl represents a mre plate of tissue.

Anatomy of the sheath of cotyledon—The term sheath of the cotyledon or cotyledonary sheath has been applied to the cap-like or sheatth like structure, the coleoptile, that enclose the plumule, and to the basal part of the cotyledon. The anatomical study of the cotyledonary sheath supports that the sheath is the basal part of the cotyledon.

Anatomy of the hypocotyl—Very occasionally the statement is given that the monocots have no hypocotyl. The basis for this statement is the shortness of the hypocotyl of many grasses hat are commonly used to illustrate monocotyledonous embryos. Very short plate like hypocotyls of monocots have received little attention anatomicaly, because of the complex structure where the transition occurs abruptly and the vascular strands like almost horizontally. The hypocotyl of some monocots has been described as 'often platelike hardly existent'. Sometimes, in certain monocots it is long and prominent in the embryo, especially where it is a part of mesocotyl. The hypocotyls of dicotyledons are normally, longer than those of the monocotyledons. The cylindrical or platelike hypocotyl is great distorted and it tends to be ovoid or spherical in seedlings of *Crocus* and *Raphanus* and in porly differentiated embryos of orchids, sapr[illegible]tes and parasites. The types of transition in vascular, structure between root and stem—from radial and exarch to collateral and endarch have been discused under the head root—stem transition.

Anatomy of the seeding root—The vascular cylinder of the primary root of seedlings is commonly diarch or tetrarch. Monarchy is rarely found in primary roots. Polyarchy is frequently found in monocotyledons. It is believed that tetrarchy is basic type since it is associated with arborescent taxa. The diarchy is associated with herbaceous taxa. The Ranunculaceae have diarch condition, whereas the woody families have tetrarch primary roots. In the dicots there are few variations from diarchy or tetrarchy. However, in the monocots

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there are many variations, but polyarchy is common, the neck, the median part, differentiated as the coleptile, and the apex, the scutellum.

In cotyledons where there is no downbending of the distal part, all he vascular bundles including those of the sides of the sheath, usually continue into the scutellum. These cotyledons, with two or four traces are simple and of primitive type. In cotyledons of advanced type, with one trace which divides to form a median and two lateral strong bundles, only the median bundle continues to the scutelum. The branches exent first upward and lateraly and then downward, on the opposite of the sheath. The course of the bundles has been considered remarkable and evidence that the coleoptile is an independent organ, not a part of the cotyledon. The position and course of the veins of sheath support the inerpretation that the upper part of sheath is stipular.

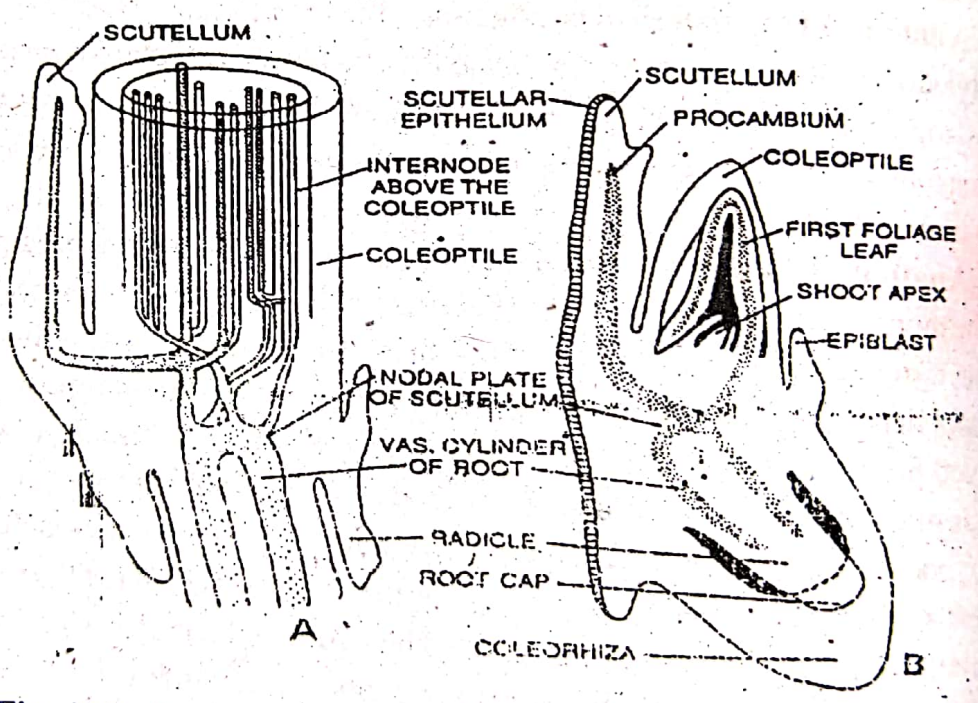

Fig. 40.2. : Anatomy of seedling of monocotyledon (wheat). A, three dimensional view of seeding of wheare B.L.s. of an entire wheat embryo.

Where there is adnation of the cotyledon neck laterally to its lower part, the midvein is bent back upon itself. The two parts are fuse and a bicollateral bundle is formed. Under continued specialization of this vascular fusion, the bundle is shortened distally and may become united with vascular stele of the hypocotyl. The shortening and adnation may extend to the point of origin of the branches of the trace of the sheath, and the branches then appear to arise directly from the hypocotyl. The origin of the trace of the sheath from the hypocotyl, shows that the sheath and the coleoptile represent the first leaf.

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